Chapter 4

Changes and Trends in Ecosystems and Landscape Features

Where to Find the Publication

The Ecological Landscapes of Wisconsin publication is available online, in CD format, and in limited quantities as a hard copy. Individual chapters are available for download in PDF format through the Wisconsin DNR website (http://dnr.wi.gov/, keyword "landscapes"). The introductory chapters (Part 1) and supporting materials (Part 3) should be downloaded along with individual ecological landscape chapters in Part 2 to aid in understanding and using the ecological landscape chapters. In addition to containing the full chapter of each ecological landscape, the website highlights key information such as the ecological landscape at a glance, Species of Greatest Conservation Need, natural community management opportunities, general management opportunities, and ecological landscape and Landtype Association maps (Appendix K of each ecological landscape chapter). These web pages are meant to be dynamic and were designed to work in close association with materials from the Wisconsin Wildlife Action Plan as well as with information on Wisconsin's natural communities from the Wisconsin Natural Heritage Inventory Program.

If you have a need for a CD or paper copy of this book, you may request one from Dreux Watermolen, Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.

Photos (L to R): White-tailed doe, photo by Vicki Sokolowski; spring blue-eyed-Mary, photo by Kitty Kohout; Kirtland's Warbler, photo by Dean DiTomasso; West Virginia white butterfly, photo by Mike Reese; gray wolf pup, photo by Brian Collins.

Suggested Citation

Wisconsin Department of Natural Resources. 2015. *The ecological landscapes of Wisconsin: an assessment of ecological resources and a guide to planning sustainable management.* Wisconsin Department of Natural Resources, PUB-SS-1131 2015, Madison.

Suggested Citation for This Chapter

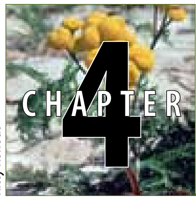
Wisconsin Department of Natural Resources. 2015. Changes and trends in ecosystems and landscape features. Chapter 4 *in The ecological landscapes of Wisconsin: an assessment of ecological resources and a guide to planning sustainable management.* Wisconsin Department of Natural Resources, PUB-SS-1131E 2015, Madison.

Kitty Kohout

Contents

LIST OF FIGURES

LIST OF TABLES



Kitty Kohout

Changes and Trends in Ecosystems and Landscape Features

This chapter discusses changes in the ecological resources of Wisconsin from the beginning of the Holocene to the time of Euro-American settlement and the many changes that have occurred since the state was settled by Euro-Americans, including changes in land use, aquatic resources, and flora and fauna. The chapter also provides information on why some ecological resources are scarce and others are now degraded.

Changes During the Holocene

The Holocene geological epoch began around 11,500 years ago as the last Pleistocene glaciation was ending, and it continues until the present. It is considered an interglacial period with a relatively warm and stable climate during which human civilization has flourished.

A long history of geologic and climatic fluctuations preceded the Holocene. During the last 2.5 million years, cycles of warmer and cooler conditions have occurred due to changes in the earth's orbit around the sun. These climate cycles, or ***Milankovitch cycles***, refer to changes in the tilt and orientation of the earth's rotation axis and changes in the shape of the earth's orbit. During the colder periods, glaciers grew in size throughout the Northern Hemisphere, with the largest one, the Laurentide Ice Sheet, covering most of Canada and the northern United States. For about the past 700,000 years, glaciations have occurred on approximately a 100,000-year cycle (Figure 4.1).

The most recent cycle of glaciation began about 115,000 years ago, and the Laurentide Ice Sheet reached its maximum southward position about 21,000 years ago. Most of Wisconsin was underneath the Laurentide Ice Sheet, and most of the state's landscapes were shaped by the flow of ice and by the large lakes and rivers that carried the meltwater away. The ice began melting 16,000 years ago, and glaciers were gone from Wisconsin by about 9,500 years ago (WGNHS 2010).

Global temperature variations during the Holocene are small (2°C) relative to the large swings characterizing glacial-interglacial periods (10°C), but temperature variations combined with changes in rainfall have had profound effects on human societies and natural ecosystems. The size and dates of climate shifts have been identified through many different kinds of evidence, including studies of fossil pollen (Figure 4.2), ***phytoliths***, plant macrofossils, sediment accumulation rates, charcoal in sediments, magnetic properties of sediments, changes in lake levels, and oxygen and carbon isotopes from lake sediments and cave formations. The record is incomplete, and research continues in this area.

Holocene climatic trends in eastern North America were controlled by ***insolation*** and the amount of glacial ice, along with ocean surface temperatures (Webb et al. 1993). Because of Milankovitch cycles, the beginning of the Holocene received 8% more solar radiation in summer and 8% less in winter relative to current conditions (Brugam et al. 2004). Early Holocene climates in Wisconsin and adjacent areas were unlike any climates found today, with a large seasonal range in temperature caused by the stronger-than-present seasonal cycle in insolation and by somewhat dryer-than-present conditions (Bartlein et al. 1998, Webb et al. 1998). About 6,000 years ago, July insolation was still about 5% greater than at present. This was the time of greatest summer warmth in eastern North America (Webb et al. 1993). Figure 4.3 shows temperature anomalies in Europe during the Holocene, based on pollen studies (Davis et al. 2003). It is unknown how closely these temperature trends approximate conditions in North America, but in Europe, temperatures were at their hottest about 6,000 years ago.

Atmospheric circulation patterns linked to glacial ice and ocean temperatures have a strong effect on climate in the Great Lakes region. It has been proposed that during the early Holocene, while the Laurentide Ice Sheet still persisted at higher latitudes, cold, dry Arctic air masses predominated over northern Wisconsin and Upper Michigan, while moist Gulf air extended into southern Wisconsin. Meanwhile, Pacific air

Terms highlighted in green are found in the glossary in Part 3 of this publication ("Supporting Materials"). Naming conventions are described in Part 1 in the Introduction to the book. Data used and limitation of the data can be found in Appendix C, "Data Sources Used in the Book," in Part 3.

masses may have controlled the climate of Iowa, Minnesota, and possibly part of northwestern Wisconsin, leading to earlier postglacial warming and drying in these areas (Baker et al. 1992). At about 5,300 years ago, the area dominated by Arctic air is thought to have shifted northward so that moist Gulf air was able to reach northern Wisconsin and Upper Michigan (Brugam et al. 2004). At around the same time, dry Pacific air masses extended into southwestern Wisconsin more frequently, causing a shift to more arid conditions. Arctic airflow may have increased after about 3,000 years ago, bringing cool air further south (Baker et al. 1992).

The Holocene climate history of Wisconsin generally follows the regional history, with a peak in summer warmth during the early and middle Holocene and dryer-than-present conditions during the middle Holocene. However, the dates and extent of key climatic events vary from one location to another. Ice sheets were gone from far southern Wisconsin about 2,000 years before they retreated out of northern Wisconsin, which contributed to differences in climate history between the two regions of the state.

Temperature and aridity both fluctuated during the mid to late Holocene but not in the same pattern. Some climates were relatively warm and dry, while others were warm and moist, cool and dry, or cool and moist. The time of maximum warmth and dryness in the Midwest was about 6,000 to 7,000 years ago (Webb et al. 1993), but drying was spatially variable, and Wisconsin locations dried somewhat later than the Great Plains (Williams et al. 2010). Highest temperatures in eastern Iowa occurred from about 6,000 to 3,000 years ago, and maximum aridity occurred from 8,000

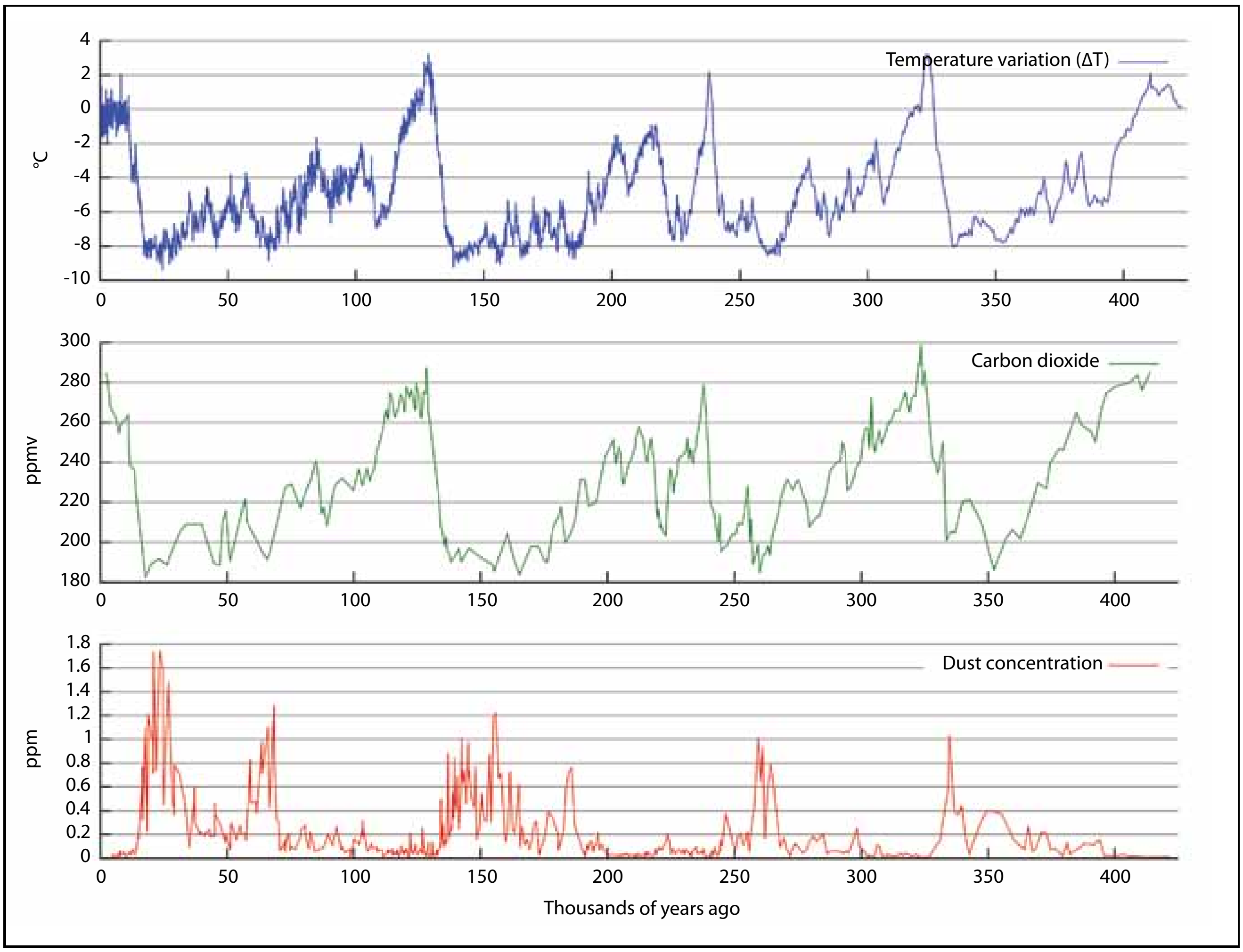


Figure 4.1. *Long-term records of climate and greenhouse gases for the past 420,000 years from the Vostok ice core, Antarctica. The blue curve represents temperature (expressed as differences from present Antarctic temperatures), the green curve gives CO_2 concentration, and the red curve shows windblown glacial dust (loess). The cyclic nature of glacial-interglacial periods is evident in all three curves, with the length of a glacial cycle averaging about 100,000 years. Reprinted by permission of Macmillan Publishers Ltd:* Nature. *Petit, J.R., J. Jouzel, D. Raynaud, N.I. Barkov, J. M. Barnola, I. Basile, M. Bender, J. Chappellaz, M. Davis, G. Delaygue, M. Delmotte, V. M. Kotlyakov, M. Legrand, V.Y. Lipenkov, C. Lorius, L. Pepin, C. Ritz, E. Saltzman, and M. Stievenard. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica.* Nature *399:429–436. Copyright 1999.*

to 4,000 years ago (Clark et al. 2001). Baker et al. (2002) found that maximum aridity occurred in southern Wisconsin between 5,500 and 3,500 years ago. Brugam et al. (2004) suggested that Upper Michigan was "drier than locations farther south in Wisconsin" prior to 6,000 years ago, and then the climate became moister.

Mid-Holocene Climate Shift in Southern Wisconsin

During the mid-Holocene, the southern Wisconsin climate became dryer and hotter. Evidence for this drying has been found at a number of lakes and mires in southern Wisconsin, including Devils Lake, Lima Bog, Washburn Bog, Hook Lake Bog, Lake Waubesa, and Lake Mendota (Winkler et al. 1986, Winkler 1988, Baker et al. 1992). The estimated timing of this drying varies from about 6,500 years ago to 5,500 years ago. The severity of drying varied spatially, and was strongest in southwestern and south central Wisconsin where precipitation was estimated to be 12%–18% less than current amounts during the dry period (Winkler 1988). This drying triggered a major shift in vegetation composition (Figure 4.2). Mesic forests in southwestern Wisconsin were common prior to the drying trend but were replaced by more drought-tolerant and fire-tolerant oak forests and savannas (Baker et al. 1992).

The southern Wisconsin climate shifted again to moister conditions about 3,500 years ago. Lake levels rose, summertime solar radiation decreased, and precipitation increased (Winkler 1988). Baker et al. (1992) noted a rise in birch pollen beginning at around 3,400 years ago at Devils Lake, attributed to the southward migration of species from the conifer-hardwood forest and indicating a general cooling trend. Birch pollen did not increase at Lima Bog in far south central Wisconsin. By 3,000 years ago, lake levels throughout the region were similar to the present (Webb et al. 1983).

Figure 4.2. *This figure (Maher 1997) shows a pollen diagram of the Holocene for sites at Devils Lake (Sauk County) and Kellners Lake (Manitowoc County), providing comparisons of vegetation in south-central Wisconsin and eastern Wisconsin. The short horizontal line segments at the left and right margins indicate thousands of years before present. Devils Lake pollen is shown in red and Kellners Lake in green. Both sites were initially forested with spruce* (Picea *spp.*) *at about 13,000 years ago. Ash* (Fraxinus *spp.*) *was higher at Devils Lake at about 10,000 years ago, while there was more pine* (Pinus *spp.*) *at Kellners Lake. Oak* (Quercus spp.) *decreased at Kellners Lake after about 5,000 years ago, and birch* (Betula *spp.*) *and pine increased. Decreases in elm* (Ulmus *spp.*) *and ironwood* (Ostrya *spp.*) *were greater at Devils Lake. The pollen of both beech* (Fagus *spp.*) *and hemlock* (Tsuga *spp.*) *occur at Devils Lake, but beech did not grow in that area, which illustrates one of the problems with pollen analysis. Pollen can be windblown for long distances, so climate inferences require correlation with other evidence. The time of Euro-American settlement is indicated by the sharp increase in ragweed (Ambrosia) pollen at the top of the diagram. Figure reproduced courtesy of Louis J. Maher, Department of Geoscience, University of Wisconsin-Madison.*

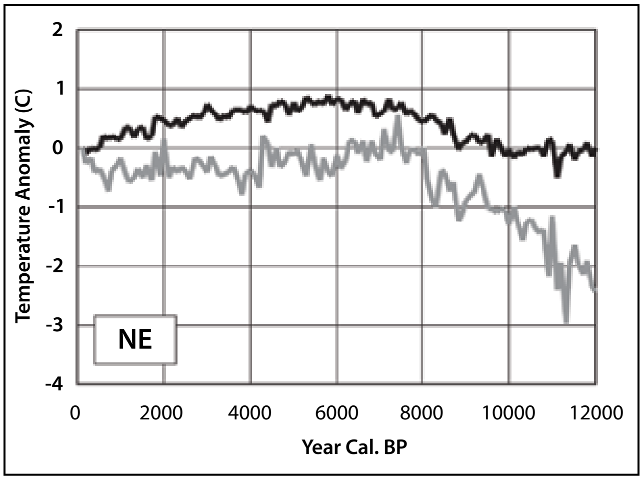


Figure 4.3. *Annual temperature fluctuations in Europe over the past 12,000 years, reconstructed from fossil pollen samples. Figure reproduced from* Quaternary Science Reviews *(Volume 22), B.A.S. Davis, S. Brewer, A.C. Stevenson, and J. Guiot, "The temperature of Europe during the Holocene reconstructed from pollen data," pages 1701–1716, 2003, with permission from Elsevier.*

Mid-Holocene Climate Shift in Northern Wisconsin

At around 8,000 to 7,000 years ago in northern Wisconsin and much of Upper Michigan, precipitation and January temperatures were lower than recent values, and July temperatures were slightly higher (Calcote 2003). Arbogast and Packman (2004) described sand dune mobilization at around 7,000 years ago in the Baraga Plains of Upper Michigan, in a dry climate with strong winds. These conditions changed by around 6,000 years ago, with precipitation and January temperatures increasing slightly and summer temperatures gradually cooling, but the change was relatively slight in comparison with mid-Holocene climate shifts elsewhere in the Midwest (Williams et al. 2010). At about this time (6,500 to 5,500 years ago), eastern hemlock (*Tsuga canadensis*) expanded rapidly across Upper Michigan apparently in response to moister conditions and also as part of a broader expansion of the range of eastern hemlock in eastern North America (Davis et al. 1986, Calcote 2003).

In contrast to southern Wisconsin, there is little evidence that northern Wisconsin experienced a major long-term drying during the middle Holocene (Calcote 2003). However, northern Wisconsin experienced several intense droughts during the last 5,000 years, lasting decades to centuries (Booth et al. 2006). One of these may have triggered the widespread collapse in hemlock populations around 5,500 years ago (Calcote 2003); another drought around 4,200 years ago may have been part of a widespread drought that spanned mid-continental North America (Booth et al. 2005). Over the last 2,000 years, at least six extreme droughts struck northern Wisconsin, Minnesota, and Michigan (Booth et al. 2006). These droughts triggered major changes in forest composition, forest fires, and, in drier areas, the reactivation of previously stabilized dune systems (Booth et al. 2005).

Over the last several thousand years, moisture availability has increased, although periodically interrupted by drought. Yellow birch (*Betula alleghaniensis*) began an expansion through Upper Michigan about 4,500 years ago at a time when the climate changed again to moist conditions. The increased effective moisture correlates with high water levels in the Michigan basin at the time of the ***Nipissing phase*** of the Great Lakes (Jackson and Booth 2002). Eastern hemlock again expanded after 4,000 to 3,500 years ago, corresponding with increases in effective moisture and cooler July temperatures (Calcote 2003). A period of increased moisture occurred again around 3,000 years ago, during the Algoma stage of Lake Michigan, and correlated with another expansion of hemlock and yellow birch (Jackson and Booth 2002, Calcote 2003).

Late Holocene

The Late Holocene period generally refers to the past 2,000 to 3,000 years. Climatic fluctuations included the Medieval Warm Period, from about 1000 A.D. to 1250 A.D., and the Little Ice Age, from about 1450 to 1850 A.D., although there is not agreement on the starting and ending dates as they undoubtedly varied regionally. As the names imply, the Medieval Warm Period was slightly warmer, and the Little Ice Age was cooler as well as wetter and stormier (Figure 4.4).

In their study of the Sylvania Wilderness in Upper Michigan, Davis et al. (1998) found that hemlock stands became established in areas that were dominated by white pine about 3,000 years ago, and eastern hemlock was able to maintain its dominance within these patches until modern times. During this period, sugar maple (*Acer saccharum*) and American basswood (*Tilia americana*) became gradually more dominant in areas not captured by eastern hemlock, displacing eastern white pine (*Pinus strobus*), red maple (*Acer rubrum*), and oak (*Quercus* spp.) (Davis et al. 1993). These changes are thought to be associated with increasing moisture during the past 4,000 years, as evidenced by gradually rising water tables (Davis et al. 1998).

In the Northwest Sands Ecological Landscape, an area dominated by jack pine (*Pinus banksiana*) and red pine (*Pinus resinosa*) at 1250 A.D. (near the end of the Medieval Warm Period) shifted to an increased abundance of white pine over the next hundred years, while the abundance of charcoal found in sediments diminished (Hotchkiss et al. 2007). This timing corresponds with changes near the Tension Zone in Lower Michigan where forests dominated by American beech (*Fagus grandifolia*), maple, and other mesic hardwoods transitioned to oak- and pine-dominated forests. These vegetation changes may be related to ***decadal droughts*** at about 1,000, 800, and 700 years ago, when atmospheric circulation patterns led to increased dominance by dry Pacific air (Hupy

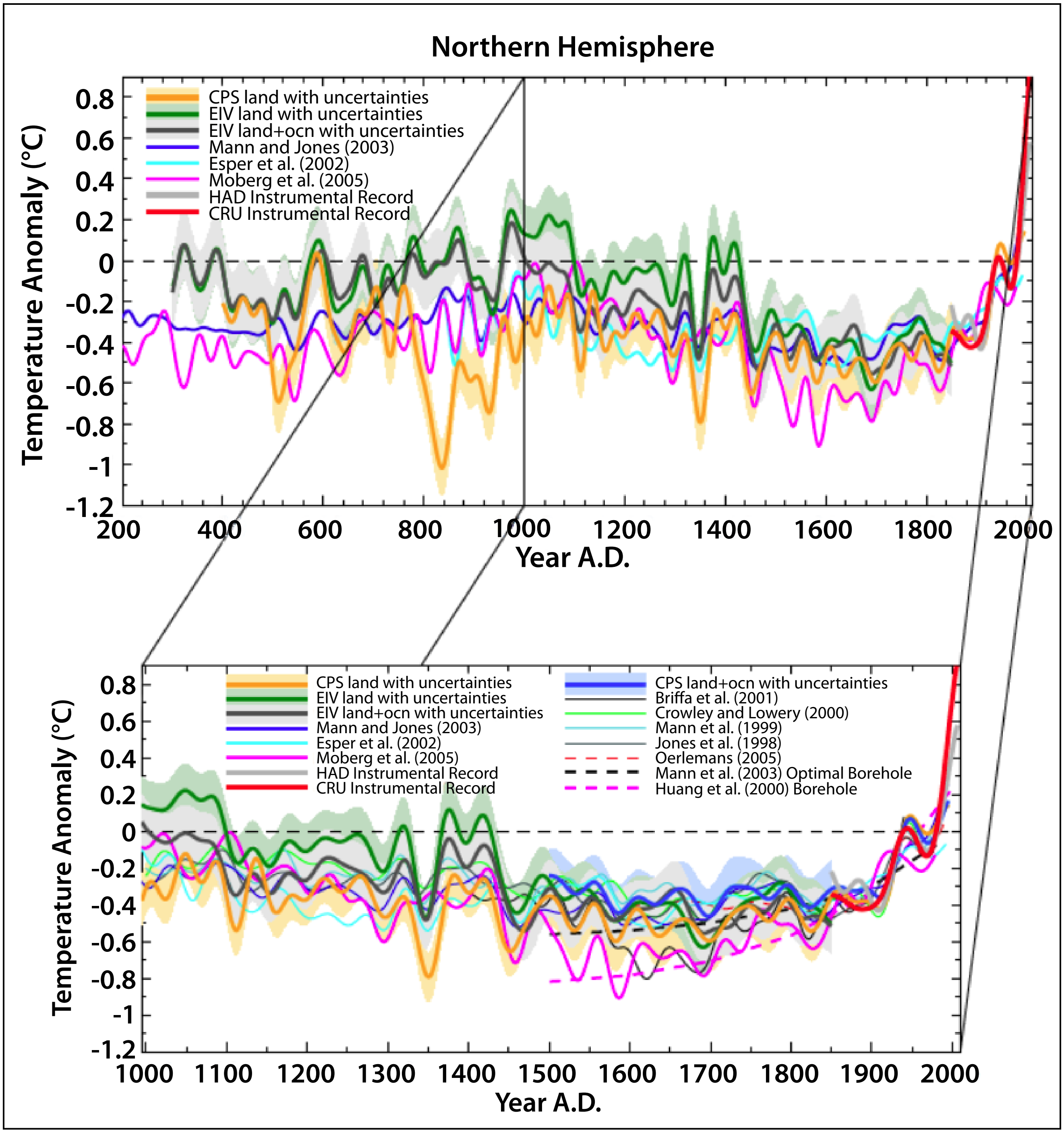


Figure 4.4. *Temperature variations for the past 1,800 years and for the past 1,000 years. The slightly warmer conditions from about 1000 to 1250 AD are known as the Medieval Warm Period, after which temperatures cooled again during the Little Ice Age, from about 1450 to 1850 AD. Figure reproduced with permission of the National Academy of Sciences, from Mann, M.E., Z. Zhang, M.K. Hughes, R.S. Bradley, S.K. Miller, S. Rutherford, and F. Ni. 2008. Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia.* Proceedings of the National Academy of Sciences *105:13252–13257. Copyright 2008.*

and Yansa 2009). Studies at Hells Kitchen Lake in the ***Winegar Moraines*** (North Central Forest Ecological Landscape) indicated a similar time frame for a gradual shift from forests of eastern white and red pine, aspen (*Populus* spp.), oaks, and white birch (*Betula papyrifera*) to forests dominated by eastern white pine, eastern hemlock, and yellow birch (Swain 1978). At about the same time, the Big Woods of southeastern Minnesota transitioned from an oak-dominated forest to one of elm (*Ulmus* spp.), sugar maple, and American basswood; tree species dominance also changed at sites in Lower Michigan (Hupy and Yansa 2009). These shifts are thought to be due to the changing climate of the Little Ice Age (Hotchkiss et al. 2007), which led to moister conditions and longer intervals between forest fires (Swain 1978, Umbanhowar 2004).

Vegetation Change During the Holocene

Following the retreat of glacial ice sheets, plant species moved northward and westward at different rates from their ***glacial refugia*** in the southern and southeastern U.S. The establishment of tree species at different times is related to climate and migration rates. The movement of hemlock, at the rate of 5 kilometers per century, is thought to have corresponded with climatic changes (Davis et al. 1993). Migration rates of tree species varied because of differences in their dispersal and survival mechanisms and competitive abilities and because of the presence of geographic barriers to migration such as Lake Michigan. Table 4.1 lists a rough sequence of vegetation change for southern and northern Wisconsin.

Boreal species were the first to advance into Wisconsin after ***deglaciation*** because conditions were still very cold. Vegetation of northern and southern Wisconsin diverged following the boreal stage, with southern forests made up of deciduous trees whose dominance and abundance changed with moisture conditions and northern forests on richer sites supporting consecutive stages of jack pine, eastern white pine-red oak, and hemlock-hardwood forests. Eastern hemlock was the last of the modern tree species to arrive, about 3,000 years ago (Davis et al. 1998). The average climate and tree species ranges in our area have been relatively stable for the past 3,000 years, but variations in atmospheric circulation have led to shifts in species' dominance (Webb et al. 1983, Tweiten et al. 2009).

The influence of site is apparent in the vegetation history of northern Wisconsin and Upper Michigan in the persistence of jack pine on outwash sands (Brubaker 1975) and interactions of site and climate that differentiate vegetation (Ewing 2002). However, under some climates, forest communities were insensitive to substrate across a wide range of intermediate sites. Pine forests, and especially eastern white pine, expanded on soils of intermediate texture during the warm, dry conditions of the mid-Holocene (about 8,000 to 5,000 years ago), but hardwoods that we now associate with heavy till soils were able to occupy these sites under cooler, wetter conditions (Graumlich and Davis 1993). Davis et al. (1993) noted that "changing climate can make substrate differences that are unimportant under one climatic regime critical under another."

Fire Interactions

Effects of climate on fire cycles are complex. Clark et al. (2001) noted that decreases in aridity during the last 2,000 years led to an increase in the productivity of tallgrass prairie, which increased fuel load and also increased fire frequency. Aridity may or may not increase fire frequency depending on how it affects plant growth and fuels. As an example, Shuman et al. (2009) found that the development of the Big Woods

Table 4.1. *A generalized vegetation sequence for northern and southern Wisconsin during the Holocene.*

Time period	Vegetation
Southern Wisconsin; near Devils Lake (Winkler 1988, Baker et al. 1992)	
13,500 to 12,000 years ago	Spruce, tamarack, black ash, sedges
12,000 to 10,000 years ago	A succession of forests dominated by fir, birch, black ash
10,000 to 5,500 years ago	Mesic deciduous forest, including elm, black ash, pine, and ironwood, with a relatively closed canopy
5,500 to 3,500 years ago[a]	Xeric oak forest and savanna
3,400 to 150 years ago	Oak forests with more closed canopies; a slight rise in birch
Northern Wisconsin and western Upper Michigan; Sylvania Wilderness Area (Davis et al. 1993, Brugam et al. 1997)	
10,000 to 9,700 years ago	Spruce dominant at beginning; gradual replacement by jack pine
9,700 to 8,000 years ago	Jack pine, with some birch
8,000 to 3,000 years ago[b]	White pine, red oak, red maple; minor amount of sugar maple
3,000 to 150 years ago	White pine declines; replaced by hemlock, yellow birch, sugar maple, basswood

[a]At this time, beech, birch, and pine increased in eastern Wisconsin within the range of beech, and oak (*Quercus* spp.) declined (Webb 1987). See also Figure 4.2.

[b]Note substrate influence on vegetation history. Jack pine forests on sandy sites were insensitive to climate change for the past 8,000 years (Brubaker 1975).

of Minnesota, which replaced savanna and open woodlands when fire severity declined, was not due to moister climatic conditions as previously thought. They inferred that droughts reduced the amount and connectivity of grass fuels in woodlands, allowing forests to expand.

Relatively small climatic fluctuations have interacted with vegetation and landscape factors to influence fire frequency and intensity during the late Holocene (Hotchkiss et al. 2007). Observations from sites in the Northwest Sands suggest that moisture balances over the last 2,000 years fluctuated on a multi-decadal scale rather than droughts or moisture surpluses occurring on a scale of a century or more. Moisture variability at this time scale may interact with ecological processes (e.g., mortality and species establishment), which act as feedbacks to influence fire and succession (Tweiten et al. 2009). Davis et al. (1993) described feedbacks due to hemlock invasion; the change in litter type and humid conditions in hemlock stands would have reduced the probability of fire spread, giving hemlock a competitive advantage over white pine and oak.

Implications for Future Climate Change

Biologists and climate scientists are looking with renewed interest at ***paleoecological studies*** to gain insights on how vegetative communities might change in the next century in response to changing climate. The significant climate shift during the mid-Holocene has been studied more often than the other, milder fluctuations, but the mid-Holocene is unlike current climate change in that it represented a shift from a long period of warming temperatures to one of general cooling. The Medieval Warm Period was a time when the regional climate became slightly warmer and drier, but the temperature increase was at most only about 1°C, and temperature increases during the past few decades may have already exceeded it (National Research Council 2006). Minor climate fluctuations are difficult to detect in paleoecological records, and the Medieval Warm Period's effects are not as well documented as those of the mid-Holocene shift (Hupy and Yansa 2009). Vegetation in northern Wisconsin during the Medieval Warm Period was dominated by jack and red pine forests on sandy sites and a mixture of eastern white and red pine, aspen, oaks, and white birch on richer sites (Swain 1978, Hotchkiss et al. 2007). Near the Tension Zone in Lower Michigan, vegetation changed from mixed mesophytic forest to a forest dominated by oak and pine during the Medieval Warm Period (Hupy and Yansa 2009).

The following general observations about the Holocene may be pertinent to future climate change:

- There were no climate shifts during the Holocene that were substantially like the current climate changes (i.e., the variations in temperatures were smaller than those projected for this century).
- Hydrological variability was large during the Holocene, particularly in southern Wisconsin. Hydrological variations included periods of aridity that lasted millennia and intense droughts that lasted decades to centuries. These periods of aridity and drought had major impacts on forest composition and water availability in the state.
- The widespread eastern hemlock decline around 5,500 years ago has been linked both to drought and to a widespread outbreak of a pest or pathogen (Calcote 2003, Shuman et al. 2004), suggesting that climate change and pests can interact to have severe impacts on tree abundances.
- Some vegetative communities have been sensitive to small temperature changes of 1–2°C (e.g., forests at the Tension Zone: Hupy and Yansa 2009). Winkler (1988) noted rapid change in wetland communities with changes in water levels. Jack pine forests on sandy sites, however, were insensitive to climate change during the past 8,000 years (Brubaker 1975).
- Climates of different parts of the state have varied from each other during the Holocene, particularly with regard to moisture; this is due to atmospheric circulation patterns that are largely controlled by ocean surface temperatures (Webb et al. 1993) with feedbacks from soil moisture (Zhang et al. 2008).
- The distribution and abundance of plant species during the Holocene was closely controlled by climate, both locally and across eastern North America.
- Novel ecosystems may develop, and the role of substrate in controlling ecosystem development may change. Minor differences in soils and landforms may become a factor in limiting the ability of a species to persist or expand; alternatively, current limits may no longer restrict species (Davis et al. 1993).
- Established tree species are able to persist through some periods of adverse conditions, although they may decline in density or stop expanding their range during these times (Jackson and Booth 2002).
- Changes in disturbance regime such as fire may change in ways that are counterintuitive (Hotchkiss et al. 2007, Shuman et al. 2009). Fire frequency can sometimes decrease in a more arid climate because of the loss of biomass and fuels in droughty conditions (Shuman et al. 2009) and at other times can decrease in a warming climate if moisture increases. Frelich and Reich (2009) noted the relatively frequent fire intervals (50–100 years) during the Little Ice Age in the boreal forests of northern Minnesota and the much longer intervals (>700 years) since 1910. They suggested that the warming climate has allowed humid air masses from the Gulf of Mexico to reach further north, contributing to longer fire cycles.

Land Use Changes

Historical and current land uses are discussed throughout this publication because they are intimately tied to ecosystem management and have dramatic and often long-lasting ecological impacts. Here, we briefly summarize some of the major themes that have shaped and continue to shape Wisconsin's landscapes. See other portions of this publication for more information, including the "Statewide Community Assessments" and the "Statewide Socioeconomic Assessments" sections of Chapter 2, "Assessment of Current Conditions," and the 16 ecological landscape chapters. In addition, see *The Vanishing Present: Wisconsin's Changing Lands, Waters, and Wildlife* (Waller and Rooney 2008) for an excellent collection of writings covering some of the major changes.

Pleistocene to Euro-American Settlement

Portions of Wisconsin have been impacted by humans since the glaciers receded 10,000–12,000 years ago, although we cannot quantify the impacts that occurred prior to Euro-American settlement. American Indians are thought to have had a major role in shaping and maintaining certain habitats and natural communities. Numerous large mammals became extinct between 12,000 and 9,000 years ago, and there is currently much debate regarding the role of humans in these extinctions relative to changes in climate and other factors (e.g., Grayson and Meltzer 2003, Fiedel and Haynes 2004, Burney and Flannery 2005). In any event, these extinctions likely resulted in major changes to the food web and the ecosystems of that time. Similarly, we cannot accurately assess the number and impacts of human-caused fires, but fire was critical in shaping much of Wisconsin's historical landscape, particularly south of the Tension Zone, and humans are thought to have been a major contributor. Other more localized land use changes by American Indians would have included food gathering, clearing for agriculture, and plant introductions (Curtis 1959).

Curtis (1959) estimated that up to one-half of Wisconsin's land surface was directly influenced by human activity prior to Euro-American settlement. Although this estimate is uncertain, we know humans had major impacts to some portions of the state. We also know that American Indians did not create the kinds of pervasive, long-lasting ecological impacts that occurred following Euro-American settlement, particularly in regard to soils, hydrology, and overall ecosystem function.

Euro-American Settlement to the Present

The public land survey of the federal General Land Office was conducted in Wisconsin from 1832 to 1866 (Schulte and Mladenoff 2001). By dividing Wisconsin into square units for future settlement and other uses, the course was set for the land ownership and use patterns that we have today. Intensive uses of the land began soon after the legal boundaries were established. The first settlers, necessarily, tried to make a living off of the land, mostly through farming. However, these efforts were unsuccessful in some areas because of soils, climate, and other factors. Fire suppression began right after Euro-American settlement, both indirectly as a result of the encroachment of Euro-American settlers into the territories of indigenous people, creating fragmentation of native ecosystems, and directly through the suppression of wildfires, which continues to this day.

Major changes to the southern half of the state following Euro-American settlement include the almost complete transformation of the original native community ***mosaic***. Here, an extensive mosaic of prairie and savanna with lesser amounts of forest became an entirely different mosaic of agricultural lands with fragmented forests between them. The majority of the prairies, savannas, and forests soon became farmlands that were either converted to crop production or grazed by livestock. Certain localized areas, such as places with steep slopes and/or shallow soils, were not farmed. By 1950 there was actually more forest in southern Wisconsin than there had been at the time of Euro-American settlement because of fire suppression, although this forest was mostly in fragmented woodlots that were only 10–60 acres on average (Curtis 1959). As fires were suppressed and forests closed, fire-intolerant and shade-tolerant tree species started to replace the more fire-tolerant and light-demanding savanna flora. Remaining prairie, savanna, and oak woodland remnants became isolated and continued to lose species diversity.

The "Cutover" was the most dramatic and long-lasting change to northern Wisconsin following Euro-American settlement. Prior to Euro-American settlement, the northern half of the state was covered by millions of acres of extensive forests; at least 60%–70% of these were mature to ***old-growth***, and there was a heavy representation by conifers (Mladenoff et al. 2008). Logging began in the mid-1800s, and by the 1930s most of the valuable timber in the northern area of the state had been removed or destroyed by fire (WDNR 2000). Forests were either clearcut or ***high graded***, a process that removes only the most valuable trees in a stand. Many attempts to farm cut-over land in the north failed. Some of the abandoned farms became what is now our current system of state-, federal-, and county-managed lands. Along with changes in ownerships, the combination of harvests and subsequent fires and farming attempts dramatically changed the species composition and structure of the northern forests, the effects of which are still seen today.

Many wetlands were drained, ditched, and/or filled following Euro-American settlement, and Wisconsin lost 46% of its total wetland area between the 1780s and 1980s (Dahl 1990). Wetland losses were most extensive in southern Wisconsin, where many were converted to agriculture or urban development. For example, 40% of the wetlands were lost between 1836 and 1990 in seven southeastern counties, and the loss was as high as 70% in Milwaukee County (SEWRPC 1997). In addition to direct losses, many wetlands have been negatively impacted by mowing, grazing, cranberry farms, hydrological manipulations, road building, and fire suppression (Zedler and Potter 2008). As with other ecosystems in the state, invasive plants and animals have severely impacted many remaining wetlands.

The major land use changes of the past continue to impact Wisconsin's native plant and animal communities. The original vegetation of southern Wisconsin has now been replaced by a combination of farms, dense forest, and urban-industrial uses, with farming often using much more intensive practices than in the past. Many species, although not completely eliminated, have been dramatically reduced in abundance. In addition to the biota, there have also been long-lasting changes to abiotic factors; for example, Kucharik (2008) estimated that the loss of prairie and savanna led to a 40%–60% decrease in soil organic matter. Even when plowing is discontinued and restoration is attempted in these systems, it can take an extremely long time for them to recover. Some planted prairies studied by Kucharik (2008) were not returning significant carbon into soils even after 20 years. The former savannas that are now forests in the south may be novel ecosystems that lack many true forest species when seed sources were not available nearby (Leach 2008).

Forests again occupy much of the state north of the Tension Zone, although forests were permanently replaced by farms and urban areas in much of Door County as well as along the Lake Michigan coastline and in large portions of the Forest Transition Ecological Landscape. The legacy of the Cutover is still evident throughout the North Woods of Wisconsin through shifts in species, land use patterns, and structural characteristics. This is true for both managed and unmanaged stands. For example, eastern hemlock is present only at 0.5% of its former abundance and, along with other former dominants such as yellow birch, is not reproducing in many of the areas in which it was formerly abundant. In addition to being dominated by large trees, the forests of the mid-1800s would have contained abundant features from previous stands such as large amounts of ***coarse woody debris*** and cavity trees. These biological legacies are greatly reduced in most forested stands now, even those not managed for timber production. Most unmanaged forests in Wisconsin are just now beginning to develop some of the characteristics associated with old growth.

Abundant hemlock saplings in the Chequamegon-Nicolet National Forest, Forest County. Hemlock regeneration taller than a few inches is now almost completely absent from most of Wisconsin. Photo by Drew Feldkirchner, Wisconsin DNR.

Contemporary Land Use Issues and Anticipated Trends

Contemporary land uses continue to dramatically shape Wisconsin's ecosystems, and there are many new and anticipated challenges for the future. The human population continues to steadily increase across the state. Growing demands on resources, which are now owned by more people in smaller parcels and with increasingly diverse interests, are likely to present many challenges for ecosystem management. Housing, urbanization, sprawl, and changes in ownership patterns often have permanent negative impacts on the state's ecosystems and present difficult predicaments for ecosystem management. The majority of Wisconsin's housing is still concentrated in the southeastern region of the state, but most areas of Wisconsin have seen significant increases in housing density in recent decades (Radeloff et al. 2005). Housing growth has been highest in the southeastern part of the state and lowest in the Driftless Area, away from major urban centers and less impacted by vacation homes than the north.

Suburban sprawl is often discussed, and its impacts are well understood. However, "rural sprawl," lower intensity development in less altered landscapes, actually has higher conservation impacts per house and leads to habitat loss, fragmentation, increases in roads, and increased potential for invasive species (UWEX Center for Land Use Education 2009). Land also continues to be converted for commercial and industrial uses. From 1982 to 1997, a total of 670 square miles of previously undeveloped land was developed; this is an area larger than the individual total size of 29 of the state's 72 counties. In addition to directly impacting existing habitats and precluding the ability to restore degraded habitats, these developments require additional use of energy and other resources.

Energy use is a complex issue with many implications for Wisconsin's ecosystems. From 1970 to 2005, energy consumption in Wisconsin increased by 55%, more than double the rate of population growth (UWEX Center for Land Use Education 2008). Currently almost all of our energy is imported from nonrenewable sources. As this has obvious implications for global ***ecosystem health***, there has been a strong push to increase our use of local renewable energy in recent years. The State of Wisconsin Office of Energy Independence (OEI), developed through a State Executive Order in 2007, developed a goal to obtain 25% of the state's energy from renewable sources by 2025 (UWEX Center for Land Use Education 2008). However, it will be extremely important for ecosystem management principles to be considered if this goal is implemented. For example, the Office of Energy Independence developed two scenarios for meeting this goal, one with and one without savings due to energy efficiency. Both scenarios call for dramatic increases in the use of woody biomass to produce energy, and the largest would require harvests to be conducted on 13.5 million acres, or 84% of Wisconsin's total forested acreage (UWEX Center for Land Use Education 2008). Harvest of woody biomass can be ecologically detrimental (see the "Bioenergy" section in Chapter 5, "Current and Emerging Resource Issues"), and care is needed to avoid reducing important habitats or depleting essential nutrients from the soil (WDNR 2009a). Virtually all types of energy require a transmission infrastructure, often leading to fragmentation or other ecologically undesirable impacts. The Office of Energy Independence was eliminated in 2012, but biomass issues will continue to be important in the future.

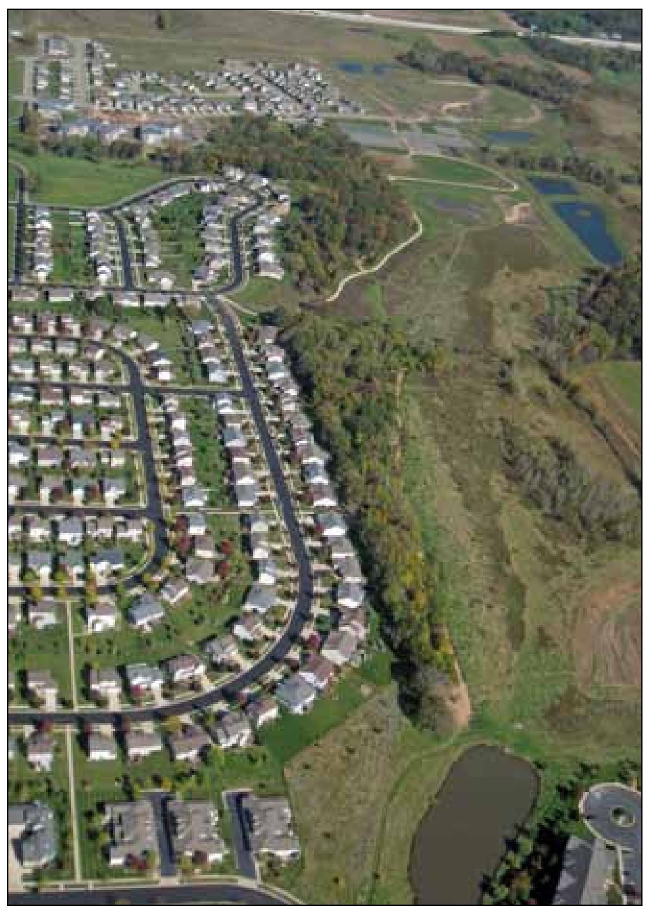
How we choose to recreate has many ecological implications for land use and ecosystem management. There is a growing divide between the population and the location of public lands in the state (UWEX Center for Land Use Education 2007). This has contributed to increased energy use, rural development, and parcelization as people visit and sometimes purchase properties to allow them to be close to the state's large public lands. There have been many changes on public lands because users desire the accommodation of new uses and the expansion of existing uses. Many of these uses require developments and stress the capacities of existing public lands to provide for all of them while meeting other important objectives, including objectives for maintaining healthy ecosystems. Some of these developments are effectively permanent, including improvements for campgrounds, some forms of motorized recreation, and associated infrastructure. Recreation facilities also continue to increase on private lands. For example, 120 new golf courses were built in the state in the last 20 years, with Wisconsin golf courses now covering 54,000 acres (UWEX Center for Land Use Education 2007).

Hydrological disruptions of the past have major impacts on the state of current aquatic systems and influence how land is used. All of Wisconsin's large rivers, most of its medium-sized rivers, and many smaller streams have been fragmented by dams (WDNR 1995). These dams affect water levels, prevent movement of aquatic species, change flow patterns, and change flooding regimes. Approximately 100 dams have been removed from Wisconsin streams since 1967 (WDNR 2008b), but many are likely to remain permanent for numerous social, economic, and ecological reasons. In many cases, dam removal may not be ecologically desirable due to buildup of contaminated sediments, movement of invasive species, and other issues.

Invasive species, although no longer a new issue, are increasingly a major concern to ecosystem function in all of the state's ecosystems, whether terrestrial or aquatic. New exotic species are continually being detected in the state, and existing invasive species are continuing to spread to previously uninfested locations. These species, both plants and animals, will continue to pose major challenges to ecosystem management in Wisconsin and can be expected to lead to major changes to ecosystem composition, structure, and function.

Wisconsin's climate has changed over the last several decades, and changes are expected to increase in coming years. Climate change will likely interact with other stressors, and ecosystem management will need to be able to incorporate new information as it becomes available. Maintaining healthy, diverse ecosystems will be important for mitigating the effects of climate change as well as providing management options.

All of these factors, and many others, can be expected to put increasing strain on our existing ecosystems. Ecosystem management can be used to help examine these issues



Housing development in southeastern Wisconsin. Photo by Ryan O'Connor, Wisconsin DNR.

from an ecological perspective, looking for opportunities to plan and manage in ways that are compatible with, or at least reduce the impacts to, ecosystem health. The ecosystem managers of the future will need to find creative ways to do more with less while encountering changing land uses and increasing human demands on the state's resources.

Changes to Aquatic Resources

When the glaciers retreated 10,000–12,000 years ago, Wisconsin was left with a large number of lakes, rivers and streams, wetlands, springs, ephemeral ponds, and abundant groundwater. These aquatic resources were subject to the natural variations of climate and other events, such as droughts, wet periods, erosion, and deposition, until Euro-American settlers arrived. Once Euro-American settlement occurred in the early to mid-1800s, both terrestrial and aquatic resources were subjected to large ecological changes. Prairies and savannas were converted to cropland and pasture; forests were logged and burned; wetlands were drained or filled; rivers and streams were dammed and channelized; commercial fishing reduced fish populations; effluent from developing industries and residential areas was dumped into lakes, rivers, and streams; runoff from agricultural lands deposited sediment, nutrients, and toxins into many waterbodies; and invasive species were introduced that outcompeted native species. These changes resulted in excessive sediment deposition, eutrophication, and degradation of water quality. Aquatic communities were simplified, habitats were fragmented, populations were isolated, and the spread of undesirable invasive species reduced the ecological and socioeconomic values of many waterbodies. Other factors that changed aquatic systems included dredging, riprapping, loss of shoreline vegetation, installation of sand blankets, the placement of culverts so that they disrupted stream flow and the movement of aquatic organisms, and activities that resulted in poor water quality, abnormal water temperatures, and degraded aquatic habitats.

Numerous species of plants, insects, mussels, reptiles, amphibians, fish and birds dependent on aquatic resources are now listed as Wisconsin Endangered, Threatened, and Special Concern species (WDNR 2009b). Other aquatic species have been identified as Species of Greatest Conservation Need in the Wisconsin Wildlife Action Plan (WDNR 2005).

Below are brief summaries of changes to aquatic ecosystems. For more specific information, see the individual ecological landscape chapters.

Great Lakes

Many of the first places in Wisconsin settled by Euro-Americans were on the shores of the Great Lakes. As these settlements and their human populations grew, the shorelines and coastal habitats were heavily modified or destroyed by urban-industrial development. Rivers entering the Great Lakes were used to carry away effluent, and wetlands and other habitats adjacent to the shorelines were drained or filled. Along with increased development, erosion increased, habitat was lost, fisheries declined, contaminants entered the Great Lakes, and the water quality was degraded. The presence of contaminants has ultimately resulted in the issuance of fish consumption advisories, and the presence of bacteria and algae has resulted in the closing of public beaches.

Lake Michigan and its biota have been dramatically affected by habitat simplification, overfishing, water quality degradation, and the introductions of invasive species such as the alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), sea lamprey (*Petromyzon marinus*), and zebra mussel (*Dreissena polymorpha*). Invasive species have significantly altered aquatic communities as have angler harvest and overstocking. Of the seven cisco (or chub) species (*Coregonus* spp.) once found in Lake Michigan, only the bloater (*Coregonus hoyi*) remains in numbers sufficient to sustain their populations (WDNR 1995). Lake trout (*Salvelinus namaycush*) populations declined from commercial overfishing, and the species was extirpated through predation by the nonnative sea lamprey (USGS 2008). The introduction of nonnative salmon (*Oncorhynchus* spp.) to control the invasive alewife appeared successful for a while but resulted in large fluctuations between predator and prey species. The aquatic communities in Lake Michigan became highly unstable. Overall, biological diversity in Lake Michigan is declining. For additional information on changes affecting Lake Michigan, see the Southern Lake Michigan Coastal, Central Lake Michigan Coastal, and Northern Lake Michigan Coastal ecological landscape chapters.

The ecological changes to Lake Superior have been less pronounced. Fish communities in Lake Superior, though heavily exploited, are more stable than those in Lake Michigan, with significant natural reproduction of most trout and nonnative salmon species, including the native lake trout (WDNR 1995). Lake Superior remains relatively clean compared to the other Great Lakes, but it is threatened by airborne and waterborne pollutants. Invasive species, continuing development of important shoreline habitats (including the rich coastal estuaries), efforts to stabilize water levels, and climate change are among the major threats to the Lake Superior ecosystems. For more detail on changes affecting Lake Superior, see Chapter 21, "The Superior Coastal Plain Ecological Landscape."

Major changes to the food webs of Lakes Michigan and Superior since Euro-American settlement are discussed in detail in Kitchell and Sass (2008). These have been due to changes in the top predators, the invasion of nonnative parasites (e.g., sea lamprey) and zooplankton feeders, and declines in primary productivity that came after the invasion of the zebra mussel. Of special interest was their report that one invasive aquatic species could create conditions that facilitated invasion by others, as the zebra mussel did for the round goby (*Neogobius melanostomus*).

Inland Lakes and Ponds

Water quality and aquatic habitats in lakes and ponds in Wisconsin have changed since the time of Euro-American settlement. In northern Wisconsin, lakes and ponds were affected by logging and then lakeshore development, and in the south they were affected by landscape changes from prairie, savanna, and forest vegetation to agricultural lands and urban-industrial areas as well as by lakeshore development.

Ecological impacts of destructive logging and other land uses in northern Wisconsin during the latter half of the 19th century were immense. Without vegetative cover, slopes were prone to soil erosion, and lakes were subject to sedimentation and loss of shoreline wetlands. In recent decades there has been a steady increase in both seasonal and permanent residents, resulting in more residential development, excess runoff from lawns and roads, and the deposition of nutrients, sediments, and other pollutants into lakes. Removal of native vegetation for lawns, piers, and swimming areas has reduced habitat values for fish and wildlife (Elias and Meyer 2003). In the shallow-water zone of lakes, shoreline development has resulted in the loss of desirable aquatic vegetation, a reduction in the diversity and productivity of fishes, and the loss of coarse woody debris, which creates important habitat for many fish and invertebrates (Christensen et al. 1996).

As land was settled in southern Wisconsin, prairies and savannas were converted to agricultural and urban uses, resulting in runoff laden with sediments and excess nutrients, greater turbidity, and elevated water temperatures. Ditching, channelization, industrial point source discharges, dams and other hydrologic modifications, construction site erosion, and gravel pits have reduced lake and pond water quality and habitat. Many lakes in southern Wisconsin are affected by heavy recreational use and shoreline development, resulting in the loss of habitat and poor water quality. Lakes in northern Wisconsin are affected by the same factors but generally not to the same degree as lakes in southern Wisconsin.

Some lakes were modified by raising and stabilizing water levels with dams. Although some impoundments can provide valuable habitat for fish and wildlife, others alter the natural hydrologic characteristics and cause the reduction of native emergent and submergent vegetation needed by fish and wildlife. Years of lake level stabilization have disrupted the natural cycles of high and low water, which are needed to maintain many aquatic and wetland habitats over time.

Invasive species such as Eurasian water-milfoil (*Myriophyllum spicatum*), curly pondweed (*Potamogeton crispus*), rusty crayfish (*Orconectes rusticus*), and common carp (*Cyprinus carpio*), have replaced or reduced many native species in lakes and ponds. Common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), and reed canary grass (*Phalaris arundinacea*) have replaced native plants in wetlands and shallow water around lakes and ponds.

Atmospheric deposition of mercury, ***polychlorinated biphenyls*** (PCBs), and sulfuric acid has affected water quality and aquatic organisms in otherwise pristine lakes, even those far from human development (Webster et al. 1993, USEPA 2010).

The following changes have taken place or threaten to further change lakes and ponds:

- Altering hydrology by ditching, draining, channelizing, tiling, and diking can eliminate wetlands and shallow ponds, can cause increased velocity of storm water runoff resulting in floods, and can reduce groundwater recharge in aquifers.
- Watershed level development, especially the loss of vegetative cover and the increase in impervious surfaces in urban, exurban, and industrial areas can increase storm water runoff, causing deposition of sediments, nutrients, and contaminants into lakes and ponds.
- Poorly designed or managed septic systems, manure storage facilities, manure applications, and feedlots contribute excess nutrient loads to surface waters when they are flooded or fail. If failures are catastrophic, long stretches of streams may be severely overloaded with nutrients, leading to serious losses of fish and other aquatic organisms.
- Water level manipulations, especially permanently raised water levels (e.g., to facilitate recreational boating), may result in the destruction of or damage to biologically valuable habitats such as shallow marshes, wild rice beds, sedge meadows, and fens.
- Inland lake water levels may be negatively affected by wetland losses and land uses that prevent precipitation from recharging groundwater that feeds lakes and ponds directly or via inlet streams.
- Ownership patterns and conflicting uses by multiple landowners around lakes make it difficult to adequately protect aquatic resources when stewardship responsibilities are shared by many.

Undeveloped alkaline bog lake bordered by tamarack (Larix laricina) *and black spruce* (Picea mariana) *swamp on the far edge. Mud Lake Bog State Natural Area, Waupaca County. Photo by Thomas Meyer, Wisconsin DNR.*

- Land use practices such as home and road construction, agriculture, and timber harvest can disturb soil, leading to erosion. This results in increased sedimentation, reduced or simplified in-stream habitats (such as important spawning areas), and loss of stream stability.
- At least 11 of approximately 150 vascular plants supported by inland lakes are now listed as Wisconsin Endangered, Threatened, or Special Concern (Nichols 2008).
- In southern Wisconsin, 19 of 59 aquatic macrophytes documented in the Madison lakes could not be found after 1960 (Nichols 2008). In addition, Nichols (2008) found that macrophytes do not grow to the depths that they once did in Wisconsin lakes, apparently due to increased turbidity, and macrophyte communities produce less biomass than they did a century ago.
- Beds of aquatic macrophytes may be damaged or destroyed by careless or irresponsible use of power boats (Asplund and Cook 1997).
- Sport, commercial, or subsistence harvests of aquatic organisms can strain certain resources when not carefully regulated.
- New invasive species continue to appear, creating challenges for managers that must often be met with dwindling staff and budgets.
- Climate change, shifting precipitation patterns, and the likelihood of additional groundwater withdrawals are among the major uncertainties facing managers and conservation planners.

Rivers and Streams

During the Cutover, access to forested lands and delivery of logs to sawmills were expedited by Wisconsin's network of rivers and streams, which was used to float logs to the mills. Riverways were cleared of large woody material to allow navigation, river bottoms and banks were scoured during log drives, and deposition of bark and other woody debris changed the character of many rivers and streams in northern Wisconsin.

Dams have changed many rivers and streams in Wisconsin since Euro-American settlement. Dams range from large structures built on the Mississippi River to maintain navigation channels for barges to small water control structures in marshes and on headwaters streams. About 3,800 dams of varying sizes have been built on Wisconsin's rivers and streams. Dams change riverine habitats into lacustrine habitats, alter natural flood dynamics and sediment transport (erosion and deposition) patterns, interfere with contaminant dynamics, slow currents, increase water temperatures, and fragment aquatic habitats. Fully 50% of all impoundments assessed in Wisconsin now have impaired water quality (WDNR 2010).

Land uses that have degraded water quality and aquatic habitats in rivers and streams include the discharge of waste materials by municipalities and industry, grazing, destruction of streamside vegetation, gravel mining, channel modifications, and the spread of invasive species.

The following additional changes have already taken place or threaten to further alter rivers and streams in the future. Fortunately some progress has occurred in addressing these issues:

- Hydroelectric facilities that vary flows to produce electricity for peak demand periods have significant effects on downstream habitats. However, under Federal Energy Regulatory Commission (FERC) regulations, owner/managers must give as much consideration to the aquatic resource as is given to power generation.
- The structure, function, and composition of rivers and streams of all sizes have been altered by channelization, dredging, and riprapping in many parts of the state.
- The clearing of woody debris from shallow water streams for recreation or other purposes has diminished habitat for many aquatic organisms, including insects and fish.
- Water quality in southern Wisconsin streams tends to be poor, putting sensitive species at risk. Watersheds with a high proportion of forest or other natural cover tend to have better water quality, and this forested condition is more common in the northern third of Wisconsin.
- Flow reduction due to surface water diversion or excessive withdrawals of groundwater can diminish or destroy habitat needed by sensitive aquatic organisms.
- Safeguards to effectively manage manure and other potential agricultural pollutants have at times proven to be inadequate to protect waterways from fish kills and

Many small streams in Wisconsin are impacted by sedimentation, warming, and increased nutrient loads as a result of damage to riparian areas. Photo by Robert Queen, Wisconsin DNR.

other contaminant problems. Rules passed in 2010 need to be implemented fully.

- An increase in impervious surfaces within watersheds results in negative impacts on water quality and aquatic habitats.

Groundwater

The water quality of Wisconsin's vast groundwater resources (estimated at over two quadrillion gallons) varies greatly across Wisconsin. Some groundwater has been affected by contaminants, especially in areas dominated by agricultural and urban land uses. The primary contaminants of human origin are volatile organic compounds (VOCs), nitrates, and various pesticides. Microbial contaminants (viruses, bacteria, and parasites) are becoming increasingly serious concerns. Some natural substances in groundwater, including iron, manganese, ***sulfate***, arsenic, and radium, may also present human health concerns.

Groundwater quantity and water withdrawal issues have received more attention in recent years. For example, in parts of southern Wisconsin excessive groundwater withdrawals have reduced ***baseflow*** to rivers and streams (Hunt et al. 2001), lowered water tables and lake levels, and damaged or destroyed wetlands. State authority to regulate groundwater withdrawals that may affect surface water resources is limited.

The following concerns exist regarding groundwater resources. Some progress has been achieved in addressing these issues:

- Groundwater quality may be affected negatively by naturally occurring or human-produced contaminants. Common sources of contamination include road salt, petroleum storage, animal waste, septic systems, fertilizers, and pesticides.
- An increase of groundwater withdrawal for agricultural, commercial, and domestic uses has produced substantial declines in groundwater levels in the lower Fox River valley, southeastern Wisconsin, and parts of Dane County.
- Lowered water tables can lead to the oxidation of some organic soils, (e.g., muck soils), reducing or eliminating their capacity to support native wetland vegetation.
- Lowered water tables permit oxidation of naturally occurring arsenic, allowing it to enter water used as a drinking source.
- Lowered water tables can have major impacts on wetland vegetation, in some cases, by effectively destroying it. In the past, water tables were purposely lowered to permit other land uses (e.g., agriculture and development).
- Groundwater withdrawals may reduce the output of springs and seepages, altering the quality and quantity of water received by lakes and streams. Important microhabitats supporting habitat specialists may be destroyed.

Changes to Flora

In geologic terms, Wisconsin's flora is relatively young. In northern Wisconsin, the Laurentide Ice Sheet reached its maximum southern advance around 18,000 years ago. By 15,000 years ago, the ice had begun to retreat, and by approximately 10,000 years ago, it was gone from the northernmost parts of the state (Dott and Attig 2004). Even in the unglaciated Driftless Area, environmental conditions during the Pleistocene were far different than they are now, and this was reflected in the more boreal flora that occupied this area at the time. Additional details on past environmental conditions in Wisconsin can be found in the "Landforms and Glacial Geology," "Topography and Elevation," and "Soils" sections of Chapter 3, "Comparison of Ecological Landscapes."

Most plant species arrived in Wisconsin from centers of distribution in the southern Appalachian Mountains, the Ozark Mountains, the Great Plains, or the boreal regions (not all of which was glaciated at the same time) within the last 10,000 years. A few plant species, many of them ***rare*** in Wisconsin, reached the Upper Midwest from the Atlantic Coastal Plain, the ***Mississippi Embayment***, or the ***Western Montane*** regions. Some plants may have persisted through the last glacial advance in the Driftless Area (Curtis 1959), though at least some of the evidence is indirect and the subject remains partially unresolved. Note that virtually all of our native plant species reached Wisconsin individually—they did not arrive en masse.

Wisconsin's flora supports roughly 2,640 species, of which 1,873 are native and 767 have been introduced and are now established somewhere in the state (Wetter et al. 2001). The plant families with the largest number of taxa (species, subspecies, etc.) are the Asteraceae (390 taxa), Poaceae (259), Cyperaceae (257), and Rosaceae (190). All other plant families include fewer than 100 taxa in Wisconsin. Other sources will provide somewhat different totals of Wisconsin flora because of (1) varying opinions on the rightful place in the taxonomic hierarchy at which some taxa should be recognized, (2) their acceptance by other taxonomists, and (3) the dissemination time of that information to the botanical community.

The Wisconsin DNR's Natural Heritage Inventory (NHI) program, established in 1985, currently tracks 355 species of rare vascular plants, including 73 listed as Wisconsin Endangered, 65 listed as Wisconsin Threatened, and 217 listed as Wisconsin Special Concern on the Wisconsin Natural Heritage Working List (WDNR 2009b). Six of these 355 species are also listed as U.S. Threatened. The NHI program also tracks nonvascular plants, including 47 lichens and a draft list of 79 bryophytes (mosses). All of these nonvascular plants are listed as Wisconsin Special Concern.

Several plant species are now treated as extirpated, meaning that they no longer occur as wild populations anywhere in Wisconsin. Two vascular plant species, Mead's

Spring blue-eyed-Mary, an extirpated annual plant, was last seen in Wisconsin in 1931. Photo by Kitty Kohout.

milkweed (*Asclepias meadii*) and spring blue-eyed-Mary (*Collinsia verna*), have been identified as extirpated on the Wisconsin Natural Heritage Working List. A number of other vascular plant species are treated as "historical," meaning that they have not been seen in several decades but there is reason to believe that they may still occur somewhere in the state. Six lichens are considered to be extirpated in Wisconsin by lichenologists, and a number of others are categorized as historical.

Sources of Information from Which "Changes in Flora" May Be Inferred

Direct evidence of Wisconsin's past vegetation has come from studies of plant macrofossils (e.g., buried logs, leaves, and seeds) and microfossils (e.g., pollen grains). The preservation of pollen grains and plant macrofossils in post-Pleistocene peat deposits (primarily in bogs and fens) and lake sediments has enabled paleoecologists and others to document changes in the vegetation and climate of the Upper Midwest in and around peatlands and lakes over many millennia. Two Creeks Buried Forest State Natural Area in Manitowoc County is an example of a site that has been systematically studied to determine the chronology and types of past vegetation that formerly occupied this region.

The federal General Land Office (GLO) public land surveys of the mid-19th century yielded an invaluable record of tree composition, density, and dominance. Conditions during that time are thought to have been similar to those that had been prevalent in this region over the past 2,000 to 4,000 years. In the GLO notes, the descriptions of understory vegetation and soils are brief and general, though they offer additional clues to the vegetation present at the time that large numbers of Euro-American settlers arrived in Wisconsin. Hand-drawn plat maps of the surveyed townships contain useful information on the general vegetation, disturbances such as windthrow or fire, and the location of physical features such as lakes, streams, wetlands, and topographic features.

The University of Wisconsin Plant Ecology Laboratory has archived the vegetation plot data collected by plant ecologist John Curtis, his associates, and their students in the late 1940s and 1950s. These data constituted the baseline against which other researchers were able to compare and analyze the changes that have occurred across a number of habitats in all parts of the state (Waller and Rooney 2008).

Other potential sources from which baseline data on plants might be obtained in the future include federal ***research natural areas***, state natural areas, lands administered and managed by the University of Wisconsin System, intensively botanized lands with archived records such as Apostle Islands National Lakeshore and the St. Croix National Scenic Riverway, the Grand Traverse Islands archipelago, the Chequamegon-Nicolet National Forest, Wisconsin's nine state forests and other selected state-owned lands, county forests, tribal lands (e.g., Bad River Indian Reservation and Red Cliff Indian Reservation), the Kickapoo Valley Reserve, and various projects under the direction of nongovernmental conservation organizations (NGOs).

Several NGOs have stewardship responsibilities for lands and waters that may also provide a valuable baseline for long-term vegetation studies. The Nature Conservancy and several local land trusts are among the noteworthy future sources of such information.

Plant Habitat Trends Since Euro-American Settlement

Trends in the native flora of Wisconsin's grasslands, savannas, and forests have shown many parallels. Widespread and common generalists, certain grasses and sedges, some ferns, and nonnative invasive plants are increasing in many habitats at the expense of some of the more conservative native species, especially among the forbs. In forest communities, patches are becoming increasingly similar to one another, even in some of the state's more remote and relatively undisturbed interior forests (Wiegmann and Waller 2006). See Waller and Rooney (2008) for an excellent treatment on current floristic trends in many of Wisconsin's major plant habitats.

Data on the abundance of native plants, especially understory species, are hit or miss and, for communities other than forests, may be altogether lacking beyond the local ***scale***. Details on natural communities, aquatic features, and other habitats used by native plants can be found in the 16 individual ecological landscape chapters.

The material that follows presents a greatly condensed overview of trends in native plant habitats since Euro-American settlement.

Herbaceous Communities

Prairies have been decimated in Wisconsin, as they have been throughout the Upper Midwest. Only a small fraction of 1% of the prairie acreage estimated to have been present at the onset of Euro-American settlement has persisted to this day. Primary factors involved in this loss include conversion to agricultural production, fire suppression, intensive grazing by livestock, and urban-industrial development. In addition to the outright destruction of native prairies, representation of the remnants is heavily skewed toward sites that are wet, excessively dry, steep, and/or rocky—factors that can limit other uses. In addition, most remnants are now small and isolated, and virtually all are in need of active management in one form or another.

Herbaceous wetlands include marshes, sedge meadows, fens, and wet prairies. Roughly one-half of Wisconsin's wetlands have been destroyed (Dahl 2006) due to filling, drainage, or dam construction. What is more difficult to assess is the degree to which wetlands have been altered and degraded by fire suppression, grazing, increased inputs of sediments and nutrients due to changing land uses in the local watersheds, colonization by invasive plants, groundwater withdrawals, and ***type conversions***. The latter have been common in some parts of Wisconsin, usually to change what was there previously to something more suitable for recreational purposes. While this may benefit some species (e.g., certain waterfowl), such practices will have negative impacts on plants for which the "new" habitats are no longer suitable. An assessment of the ***cumulative impacts*** of wetlands management would be useful to determine wetland community status and current conservation and management needs.

Shrublands

Shrub-dominated wetlands may be among a very small number of native vegetation types that have increased in acreage since Euro-American settlement. Often this has been due to the incomplete drainage of wetlands that formerly supported marshes, sedge meadows, fens, or bogs. In addition to ditching, diking, and tiling, the absence of periodic fire has accelerated the conversion of open wetlands to shrub dominance. In logged lowland forests, the post-logging "shrub stage" may be short- or long-lived.

Upland shrub communities are not currently recognized as distinct entities on the Wisconsin Natural Heritage Working List (WDNR 2009b). Upland shrub habitats are unstable, change rapidly, and usually represent a short-lived stage in plant succession. (For example, shrubby clearcuts quickly become young forests and are very difficult to track and map over time for an area as large as a state. In areas managed with relatively frequent prescribed fire, the shrub, or "grub," stage is recognized as one structural variant of oak or pine barrens communities.)

For animals, upland habitats dominated by shrubs can be extremely important. The Wisconsin DNR's Natural Heritage Inventory program may recognize one or more types of upland shrub communities in the future. The specifications of such dynamic and plastic communities will have to be done very carefully.

Because many (but certainly not all) of our shrub wetlands are the product of recent disturbance, a clarification of the differences between current and historical conditions is needed.

Savannas

Savannas are dynamic natural communities that were historically maintained by periodic wildfire. Southern Wisconsin's formerly abundant oak savannas covered over 20% of the state, virtually all of which has been lost to development or succeeded to dense forests because of widespread fire suppression. As more mesophytic woody species have increased in density and abundance (Nowacki and Abrams 2008), a sharp and apparently continuing decline in light-demanding savanna understory species (including seedling and sapling oaks) has been documented by several researchers (e.g., Leach 1996, Leach and Givnish 1999).

Barrens communities were formerly common in northwestern, northeastern, and central Wisconsin in association with sandy glacial outwash plains and glacial lakebeds. Barrens were also well developed on the broad sandy terraces that border several of Wisconsin's largest rivers, such as the Wisconsin, Chippewa, Black, and Mississippi. Fire suppression, conversion to pine plantations, grazing, and attempted cultivation have altered or destroyed most of Wisconsin's oak and pine barrens, but there are significant though limited restoration opportunities throughout the former range of these communities.

Forests

The overall amount of forest in Wisconsin today is roughly equivalent to what was present in the state historically. However, structural, functional, and compositional attributes of our forests have changed dramatically. (See the "Northern Forest Communities" and "Southern Forest Communities" sections of Chapter 2, "Assessment of Current Conditions.") Large live and dead standing trees, large coarse woody debris, large patches, and patch connectivity are among the diminished and declining vertical and horizontal forest structural attributes.

Most troubling has been the dramatic decline and loss among sensitive native herbs, even in our more remote northern forests (Rooney et al. 2004). Parallel losses of native flora on "protected" lands, especially parks, in the southern part of the state (Rogers et al. 2008) have been equally troubling, though perhaps somewhat less surprising. Among the causes of change are fire suppression, hydrologic disruption, grazing by livestock, excessive browsing by white-tailed deer (*Odocoileus virginianus*) on seedling and sapling trees and understory herbs, the spread of invasive species (including nonnative earthworms [Nuzzo et al. 2009] and many invasive plants), population isolation, diseases, and management regimes that have eliminated or diminished some of the niches required by native plants.

Glaciers during the Pleistocene eliminated native earthworms from most of Canada and the northern portion of the United States (Hendrix and Bohlen 2002). It is thought that the northern limit of native earthworm populations may correspond to the extent of the ice at the peak of the Wisconsin glaciation, but it may extend to the edge of permafrost beyond the ice terminus (Hendrix and Bohlen 2002). Therefore, all earthworms in the glaciated areas of Wisconsin are nonnative species that were introduced. It is unclear if any native earthworms still exist in the unglaciated southwestern portion of Wisconsin. This area was never covered by the ice sheet, but it was almost entirely surrounded by ice, which may have resulted in permafrost conditions unfavorable to the survival of native earthworms.

Miscellaneous Habitats

In addition to the outright destruction of fragile beach and dune environments along the Great Lakes by urban and residential development, the construction of seawalls, jetties, and marinas has disrupted the natural processes that created and are necessary to sustain these natural communities. Dunes, in particular, have been invaded by aggressive plants such as the nonnative lyme grass (*Leymus arenarius*) and spotted knapweed (*Centaurea biebersteinii*) and by the native poison ivy (*Toxicodendron radicans*). The latter may spread and form an almost continuous ground layer on sites disturbed by heavy foot or vehicular traffic. The dune specialists, which include globally rare Great Lakes endemics such as dune (Pitcher's) thistle (*Cirsium pitcheri*) and Lake Huron tansy (*Tanacetum huronense*) fare poorly and may be lost from some sites.

Bedrock habitats such as cliffs, glades, alvars, and ***talus slopes*** can be destroyed by quarrying, and the flora can be very sensitive to trampling (including rock climbing). Hydrologic disruption may seriously impact cliff and talus biota, which includes highly specialized plants and animals.

Aquatic Habitats

Major changes to aquatic ecosystems include dam construction and the disruption of natural hydrologic regimes (including the periodically changing water levels upon which many native plants are dependent for their rejuvenation and continued existence); shoreline development and the loss of vegetative ***buffers*** around lakes, rivers, and streams; excessive inputs of nutrients and sediments; and the establishment and spread of invasive plants and animals. Each of these factors has negatively impacted the diversity and population sizes of native aquatic plants, and by extension, some of the native animals that are closely tied to these plants.

Lake Huron Tansy, a Wisconsin Endangered plant, is restricted in Wisconsin to the Lake Michigan shore, including sandy beaches, dunes, and limestone pavements. Photo by Kitty Kohout.

Reasons for Change to Wisconsin's Flora

Change in our environment is not only constant but is inevitable. Many changes are cyclical, and some occur over very long periods of time (millennia). Others are the result of the abrupt and often drastic ways in which humans have changed conditions for native plants and animals, directly or indirectly. Among the factors that have negatively affected native plant populations in Wisconsin in recent years and about which conservationists are especially concerned are

- habitat loss and degradation;
- habitat fragmentation and isolation of remnant habitat patches;
- habitat simplification and homogenization;
- disruption or suppression of processes upon which many of our native species are directly or indirectly dependent such as periodic wildfire and water level changes;

- introduced species (including plants, animals, and pathogens), especially those that are invasive and have the ability to spread quickly and outcompete native plants;
- overabundant native species, such as white-tailed deer, which have had serious negative impacts on some trees and understory species;
- climate change;
- exploitation and persecution of plants that are showy, thought to have medicinal values, or thought to have no value;
- public policies that can discourage, usually indirectly, the protection and conservation of native plants; for example, tax incentives to those who graze woodlots or local "weed" ordinances can have negative consequences for native plants, especially in exurban areas currently undergoing development;
- in the past, public institutions encouraging the use of species that have proven to be highly invasive (reed canary grass, multiflora rose [*Rosa multiflora*], autumn olive [*Elaeagnus umbellate*], black locust [*Robinia pseudoacacia*]), which has usually been done to provide wildlife habitat, forage, or reduce erosion; and
- inertia—once begun, government-run or supported programs develop clienteles, and such programs can then be difficult to terminate or even modify because the beneficiaries of such programs do not want them ended and may want them expanded or increased.

Other human activities can have negative effects on native plants. The methods (such as spraying herbicides) used to maintain roadsides, power line corridors, railroad lines, and other rights-of-way change as cheaper means of conducting these activities are developed. This may not only result in the outright destruction of the vegetation persisting in such corridors but also facilitate the colonization and spread of invasive plants and reduce connectivity between patches of important plant habitat, which can limit or prohibit the movement of animals, including pollinators and species that disperse reproductive propagules.

While the grazing of woodlots carries its own ecological price in terms of impacts to native flora, the cessation of grazing can result in or accelerate the rapid conversion of open understories to impenetrable thickets of nonnative, highly invasive shrubs such as multiflora rose (formerly widely planted as "wildlife cover"), Japanese barberry (*Berberis thunbergii*), and Eurasian buckthorns (*Rhamnus cathartica* and *R. frangula*) and honeysuckles (e.g., *Lonicera morrowii* and *L. tatarica*). Some native plants, such as common prickly-ash (*Zanthoxylum americanum*) and brambles (*Rubus* spp.), may behave in similar fashion. This is especially noticeable in fire-driven ecosystems such as savannas, where grazing at some level may maintain the open structure needed by the light-demanding understory plants. The downside is that many of these same plants are not well adapted to constant, relatively intensive grazing by domestic livestock and may be replaced by nonnative herbs or weedy native generalists.

In forest communities that were formerly shaped by and to a degree dependent on periodic wildfire such as those dominated by oaks and pines, the widespread implementation of fire suppression policies has led to an increase in the saplings of mesophytic trees, such as red maple, black cherry (*Prunus serotina*), and ironwood (*Ostrya virginiana*), and dense growths of native and exotic shrubs (Lorimer 1984). The result has been the loss or significant reduction of many plant species dependent on higher levels of ambient light. In addition, the proliferation of these mesophytic saplings and shrubs "resets" the entire community to respond very differently to future disturbances. The use of prescribed fire to restore and maintain the conditions that permitted the oaks (and, on many sites, pines) to thrive becomes increasingly problematic and more expensive, especially in landscapes that are becoming increasingly fragmented and parcelized. Loss of these ecologically and commercially valuable species continues in much of southern Wisconsin.

Conservation Needs for Native Flora

The stabilization or reversal of current declines in our native flora requires a better understanding of the reasons underlying these declines and the impacts of our resource use. The individual and combined effects of fire suppression, hydrologic disruption, overabundant white-tailed deer, skewed representation of size and age classes in our managed forests, a seemingly endless barrage of invasive species, including nonnative earthworms, and the continued fragmentation and isolation of native plant habitats have resulted in widespread declines or loss of native plants at stand and regional levels. Impacts from climate change are uncertain but sure to produce novel as well as potentially predictable responses from vegetation.

Many future changes will be difficult if not impossible to predict, and some of the forces now impacting our landscapes will not only continue but are likely to interact in synergistic ways that cannot be foreseen. Changes may be rapid or slow, short-lived or long-lasting, dramatic or insidious. Among the conservation needs and actions we might take in the near future to better understand and respond to these problems are the following:

- Collect better long-term baseline information; identify species and habitats at risk; and address information needs for selected species, habitats, communities, successional stages, and developmental stages by developing methods that produce accurate, efficient, and cost effective results. The value of and need for solid baseline information can hardly be overstated. This statement applies to much more than plants, of course, but we can start by expanding existing monitoring programs, assessing their adequacy across administrative and geographic boundaries, and identify gaps for which better information is needed to inform and potentially adjust management.

- Though we need data from randomly selected sites, there is perhaps an even more urgent need to collect solid baseline data from sites selected for their conservation values and the quality and representativeness of the natural communities, aquatic features, and species they contain. It is assumed that such sites will conserve native plants (and many associated animals). All natural communities, across their natural range of distribution and representing the characteristic range of variability indicative of each type, need to be included in such studies. Such a project would probably have to be prioritized, based on type rarity, the results of a risk assessment, or fiscal constraints, but eventually all types—rare and common, forested or nonforested, need to be included. Examples of a subset of sites from which such information might be obtained could include federal research natural areas, federal wilderness areas, state natural areas, reserves acquired and protected by NGOs primarily for their biodiversity values, and sites identified but not yet designated as highly significant for conservation through rigorous inventory and conservation planning processes.
- An assessment of Wisconsin's native plants that parallels the Wisconsin Wildlife Action Plan (WDNR 2005) to identify those species and habitats that are at greatest risk of decline and potential loss is needed. This could be done partly in conjunction with the efforts of the Plants and Natural Communities Working Group of the Wisconsin Initiative on Climate Change Impacts (WICCI).
- Develop and implement a more rigorous approach to the selection, planning, and management of conservation lands that takes a long view and broad approach to management and focuses on scale, connectivity, and, where feasible and appropriate, important ecological gradients.
- Last but not least, native plant inventories need to be continued and expanded. In addition to the declining trends noted above for native plants in many ecosystems, new discoveries continue to be made. Even areas as well botanized as the Door Peninsula have yielded recent records of species "new" to Wisconsin. Habitats that have been inadequately surveyed or ignored in the past (examples include the ***red clay wetlands*** in and around the City of Superior, remote peatlands in northwestern Wisconsin, and ephemeral ponds across the state) have also been the source of new and sometimes surprising species records (Judziewicz and Nekola 2000).

Plant inventories should be regarded as dynamic processes that are never "complete." In addition to the always exciting discovery of native species that are "new" to the state, inventories remain the most effective and reliable way to periodically assess the status of plant species and habitats judged to be at risk, document trends in abundance and distribution, and ensure that the best available information is used to adjust conservation priorities, management activities, and land use decisions. Such inventories may also serve as an early warning system as populations of "new" invasive plants are discovered, leading to a higher probability of early, more effective, control.

Changes to Fauna

Wildlife populations have changed dramatically on the Wisconsin landscape over the last 10,000 years, but these changes were not well documented before the mid-1800s. This section discusses changes in wildlife populations since the time of Euro-American settlement. It only discusses those wildlife species documented as having occurred in Wisconsin and for which there is information.

Wildlife populations changed once Euro-American settlers arrived. Most species declined with the massive changes that occurred to the landscape with the advent of farming and timber harvesting. In addition, many species were used for food or were considered a threat to livestock or people and were deliberately eliminated. However, some species increased, such as the eastern cottontail rabbit (*Sylvilagus floridanus*) and raccoon (*Procyon lotor*). Others increased for a while but then declined, such as the Northern Bobwhite (*Colinus virginianus*) and the Greater Prairie-Chicken (*Tympanuchus cupido*). One species, the Passenger Pigeon (*Ectopistes migratorius*) became extinct. Others were extirpated from the state, including the American bison (*Bos bison*), elk (*Cervus elaphus*), gray wolf (*Canis lupus*), cougar (*Puma concolor*), American marten (*Martes americana*), fisher (*Martes pennanti*), and Wild Turkey (*Meleagris gallopavo*). Other species populations declined but persisted in Wisconsin (e.g., white-tailed deer and the black bear (*Ursus americanus*).

After almost a century of settlement, many species were at low levels (1900s–1940s). However, some species declined even further, especially top predators, after the introduction of pesticides in the 1940s. Other species declined further through the 1960s and beyond as a result of "clean" and more intensive farming, leaving little habitat for wildlife, or from fragmentation or intensive use of forest and grassland habitats. Nonnative species were introduced, such as Ring-necked Pheasant (*Phasianus colchicu)*, Gray Partridge (*Perdix perdix*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*). Invasive species were introduced or moved into Wisconsin from neighboring states and have had impacts on native species (e.g., common carp, European Starling [*Sturnus vulgaris*], House Sparrow [*Passer domesticus*], and Mute Swan [*Cygnus olor*]).

In the last 80 years, species such as fisher, American marten, Trumpeter Swan (*Cygnus buccinator*), and Whooping Crane (*Grus americana*) have been reintroduced into the state. Some species such as gray wolf and moose (*Alces alces*) recolonized the state on their own, and other species such as Bald Eagle (*Haliaeetus leucocephalus*) and Osprey (*Pandion haliaetus*) increased in abundance once harmful pesticides such as DDT and its derivatives were banned in the 1970s. Other species such as white-tailed deer, coyote (*Canis latrans*), raccoon, and Canada Goose (*Branta canadensis*) have increased dramatically, taking advantage of the human-shaped landscape.

The changes in wildlife species composition and abundance had effects on the ecosystems in the state. Below are a few of the ways changes in faunal populations may have affected ecosystems:

- Some species such as white-tailed deer and possibly elk and American bison are considered ***keystone species***. White-tailed deer can change the composition and structure of forests if their numbers are high enough (see "White-tailed Deer Impacts on the Ecosystem" section in Chapter 5, "Current and Emerging Resource Issues"). Changes in ungulate numbers can have cascading effects on the rest of an ecosystem by modifying plant species composition and structure and affecting use by other species.
- When large predators were removed (for example, gray wolf and cougar), ungulates may have increased survival rates, providing an additional factor to aid ungulate populations to grow. Since predators often remove the sick or old from a prey population, the health of the prey population can be affected. Insectivorous birds can impact insect populations, which affects forest productivity (Marquis and Whelan 1994). Piscivorous birds can impact fish populations (e.g., Double-crested Cormorant [*Phalacrocorax auritus*]). Some bird species (e.g., Blue Jay [*Cyanocitta cristata*]) are a major seed dispersal mechanism, affecting plant species composition.
- American beaver (*Castor canadensis*) populations change the nature of streams from free flowing to a series of ponds in which they build their winter lodges. This has impacts on other aquatic organisms, especially coldwater species. The snowshoe hare (*Lepus americanus*) can impact forest vegetation in northern Wisconsin when its population becomes high during population cycles, reducing forest regeneration and affecting species composition. Other small mammals such as voles (*Microtus* spp.) can also interfere with tree regeneration when their populations are high.
- Some populations of fish can have large impacts on the entire aquatic ecosystem by controlling prey that feed on plankton and other microscopic organisms. Whole lake ecosystems have been changed (e.g., Lake Michigan) when top predator populations were changed.

Wolf pup in northwestern Wisconsin. Photo by Brian Collins.

Wildlife communities are much different than they were at the time of Euro-American settlement. Changes in the composition and abundance of faunal communities over time have had impacts on most of the ecosystems in the state. However, these changes were not nearly so extensive as the changes that occurred from the settlement of the land by Euro-Americans. Further changes to the composition and abundance of faunal populations are likely with the added stressors of development, pollutants, invasive species, and climate change. Managing to sustain as many wildlife species and the habitats that they use will be important to maintaining functioning ecosystems in the future. For a more complete review of historical wildlife in the state, see a collection of articles written by A.W. Schorger, compiled in a volume entitled *Wildlife in Early Wisconsin: A Collection of Works by A.W. Schorger* (Brockman and Dow 1982) and articles in *The Vanishing Present: Wisconsin's Changing Lands, Waters, and Wildlife* (Waller and Rooney 2008).

Changes in Animal Communities

This section provides a synopsis of changing animal communities. See the "Individual Species Changes" section of this chapter for detailed accounts of changes to individual wildlife species for which more information was available. Some of the information in this section is heavily based on *The Vanishing Present: Wisconsin's Changing Lands, Waters, and Wildlife* (Waller and Rooney 2008), a collection of essays giving historical perspective, an overview of present ecological changes, and future impacts. Authors of essays in *The Vanishing Present* are cited at the beginning of the relevant sections.

Mammals

The following section discusses the changes to mammal communities since Euro-American settlement. Mammal communities such as ungulates, carnivores, and medium- and small-sized mammals are discussed.

Ungulates

Ungulate populations declined with the arrival of Euro-American settlers in Wisconsin. These species were used for food and clothing as well as shipped to markets in eastern cities to feed the growing number of citizens there. American bison were likely gone by the time settlers arrived (1830s), and elk disappeared shortly thereafter (1860s). Moose were mostly found in the northern third of Wisconsin but were gone by 1900. White-tailed deer were greatly reduced in numbers by the early 1900s and were scarce in southern Wisconsin until the mid-1960s. In the north, white-tailed deer populations increased in abundance after the Cutover, when abundant food was available in the regrowing forest. White-tailed deer became very abundant in the north by the 1940s and likely had an impact on the composition of trees and herbaceous plants in the forest. White-tailed deer populations in both northern and southern Wisconsin increased substantially in the 1980s and 1990s and remain high to this day. For more details, see the "White-tailed Deer Impacts on the Ecosystem" section of Chapter 5, "Current and Emerging Resource Issues."

Today, only the white-tailed deer remains as a prominent ungulate in the state. It is found throughout the state, from urban and agricultural areas in the south to the forests of the north. Many areas of the state have white-tailed deer populations that are at very high densities compared to historical times. A small, reintroduced herd of elk (approximately 130 animals in 2009) is present in the northern part of the state, and a very small moose population occurs in the northeastern and northwestern parts of the state, mostly from animals wandering into Wisconsin from Michigan or Minnesota.

Carnivores (Wydeven and Pils 2008)

The abundance of carnivores differs substantially from what it was prior to Euro-American settlement. ***Canids*** such as gray wolves were hunted and trapped until they were no longer existent in the state by 1960. They reentered Wisconsin from Minnesota in the late 1970s and have reestablished populations in suitable habitat in northern and central Wisconsin, with a population of over 700 wolves in 2010 (Wisconsin DNR data). At the time of Euro-American settlement, the gray fox (*Urocyon cinereoargenteus*) was more abundant in the deciduous forests of southern Wisconsin, while the red fox (*Vulpes vulpes*) occurred only in the north. Both fox species occupied most of Wisconsin by the mid-1900s. The gray fox occupied over half the state extending to Lake Superior but then declined and was found only in the southern third of the state by 1975. The red fox extended its range south and became established throughout southern Wisconsin. These animals likely represent European red fox or hybrids. The coyote lived primarily in the prairies and savannas of southern Wisconsin. By 1900 the coyote was abundant in the cut-over areas of northern Wisconsin, and today the coyote can be found throughout the state, including in major cities. It likely occurs in lower densities where gray wolf populations coexist.

The bobcat (*Lynx rufus*) was found throughout Wisconsin prior to Euro-American settlement. Due to unregulated hunting and bounties, the bobcat was only found in northern Wisconsin by the 1960s. Since then the bobcat has expanded its range into central Wisconsin and more southern parts of the state. The lynx (*Lynx canadensis*) was never abundant in Wisconsin, dispersing into the state from areas to the north when snowshoe hare populations declined. During these times, small breeding populations may have become established in northern Wisconsin. The lynx continues to be rare, with sporadic reports from northern Wisconsin. The cougar was most abundant in southern Wisconsin prior to Euro-American settlement, often reported from the river valleys and southwestern Wisconsin. Its numbers declined because of unregulated hunting and loss of prey and habitat, and the

As Wisconsin was settled by Euro-Americans during the 19th and early 20th centuries, unregulated exploitation and major habitat changes led to greatly decreased bobcat populations, and this species persisted mostly in the northernmost parts of the state. More recently, there has been some recovery in numbers as well as an expansion of range. Photo by Herbert Lange.

last cougar was reported in Wisconsin in 1909. Recurring reports of cougars have been received for decades, but only recently have there been confirmed sightings.

The fisher and American marten were broadly distributed in northern and central Wisconsin at the time of Euro-American settlement. These species lost almost all their habitat in the late 1800s and early 1900s when the northern forests were almost entirely cut and burned over. In addition, unregulated trapping contributed to their extirpation in Wisconsin. In the 1950s, efforts were made to reintroduce the fisher and American marten to Wisconsin. Fisher populations grew and expanded throughout northern Wisconsin, spreading into the central and southwestern parts of the state. The reintroduced American marten population has persisted but has not expanded greatly from the original release sites.

The badger (*Taxidea taxus*) occurred in the open prairies and savannas of southern Wisconsin at Euro-American settlement times. The badger was almost eliminated from the state by the late 1800s, but the Cutover region in northern Wisconsin provided new habitat, allowing it to persist. By the 1990s, the badger occurred in every county of the state, with the largest numbers in those parts of northern Wisconsin that have extensive barrens habitats.

The black bear occurred throughout the state prior to Euro-American settlement but was probably less frequent in the large prairie and savanna areas of southwestern Wisconsin. The black bear declined after Euro-American settlement, after which it occurred only in northern Wisconsin. The black bear has expanded its range since then and now occurs throughout northern and central Wisconsin and is occasionally reported in southern Wisconsin.

The raccoon was likely restricted to the southern part of the state at Euro-American settlement times. In the 1950s, raccoons were raised at the State Game Farm at Poynette (Columbia County) and released to increase populations. Today it is found throughout the state, including in urban areas. Highest raccoon densities in Wisconsin are found in river bottoms and agricultural areas that are well interspersed with woodlands and waterways. Since raccoons are so abundant in Wisconsin, most wildlife management emphasis is on regulating the hunting and trapping seasons to help control the size of the population.

American Beaver and Other Small Mammals

American beaver pelts were the most sought-after pelt for the fur trade and brought Euro-American traders and trappers to the state. Prior to 1800, the beaver was found throughout the state (Jackson 1961). With unregulated trapping for the fur trade, American beaver populations decreased, and the American beaver was thought to be nearly extirpated by 1900. The American beaver is again found throughout the state and is considered a problem in some northern parts of the state because it has dammed streams, making them unsuitable for trout. See the "Individual Species Changes" section below for more details.

The cottontail rabbit was found in southern Wisconsin at the time of Euro-American settlement, but it expanded throughout the state as deforestation and agriculture moved north (Jackson 1961). Aldo Leopold (1931) observed that "the cottontail, like the quail and the prairie chicken, has accompanied grain farming in its invasion of the Forest Belt." By the early 1900s, the cottontail rabbit was found throughout the state where there was suitable habitat.

The snowshoe hare occupied tamarack and northern white-cedar swamps as far south as Jefferson and Milwaukee counties at the time of Euro-American settlement (Jackson 1961). After Euro-American settlement, the snowshoe hare retreated northward (Leopold 1931, Jackson 1961). Today it is only found in central and northern Wisconsin where it is subject to population cycles. At population cycle highs, snowshoe hares can impact tree saplings and other woody vegetation.

Little is known about historical populations of most native small mammals, but it likely that populations changed with the large habitat changes that took place across the landscape of the state. Some species expanded their range northward (e.g., Virginia opossum [*Didelphis virginiana*] expanded northward since the 1920s: Jackson 1961). Species such as the Norway rat (*Rattus norvegicus*) and house mouse (*Mus musculus*) were introduced, have expanded across the state, and have had large economic impacts on stored crops and other human products.

Bats are currently threatened with a fungal disease that is causing widespread mortality across the eastern part of the country. Cave bats have been declining nationally, and over the last several years an immediate threat to their populations has been posed by the appearance of a devastating fungus, *Geomyces destructans*, which produces the fatal condition known as ***white-nose syndrome*** (WNS). As of this writing, WNS has been documented at several sites in Wisconsin. This disease could have large impacts on Wisconsin's bat populations.

At the request of the Wisconsin DNR secretary, the Natural Resources Board approved the listing of four species of cave-dwelling bats as Wisconsin Threatened at their September 2010 meeting. The four species are the little brown bat (*Myotis lucifugus*), the northern long-eared bat (*Myotis septentrionalis*), the eastern pipistrelle (*Perimyotis subflavus*), and the big brown bat (*Eptesicus fuscus*). Wisconsin has one of the highest concentrations of cave bat hibernacula in the Midwest, and many bats from adjoining states hibernate here. Listing by emergency rule is a proactive step taken by the Wisconsin DNR to recognize both the severity and immediacy of the threat from WNS. The fungus *Geomyces destructans* has been listed as a "prohibited invasive species" as a complement to the bat listing.

Birds

As a group, birds of prey (e.g., hawks and owls) declined after Euro-American settlement; they were shot or trapped because settlers thought that they were a threat to domestic animals or competed with settlers for game species. Top avian predator populations, such as Bald Eagle, Osprey, and Peregrine Falcon (*Falco peregrinus*), further declined because of eggshell thinning that occurred when DDT and other pesticides were used in the late 1940s, 1950s, and 1960s. Once these harmful pesticides were banned in the 1970s, this group of species has again increased in number.

Forest bird species likely declined after the Cutover since much of their habitat was removed, but their populations have increased again due to the regrowth of forests. Wetland bird species likely declined after Euro-American settlement since almost half of the wetlands in the state were drained or filled. Some wetland species (e.g., ducks, geese, swans, and cranes) were shot for food, further decreasing their numbers. Species able to adapt to human-changed landscapes, such as the Canada Goose, have become very abundant, but most other wetland species remain at lower numbers.

As a group, grassland birds have declined most dramatically since Euro-American settlement times (Sample and Mossman 2008). Most of Wisconsin's original prairies, meadows, barrens, and savannas were converted to agriculture shortly after the state was settled in the mid-1800s. However, the low-intensity, grass-based farming widely practiced then inadvertently sustained many grassland birds until the mid-1900s. As farming became more intensive in the second half of the 20th century with the use of artificial fertilizers, pesticides, and monoculture crops such as corn and soybeans, most grassland bird populations declined. Today grassland birds continue to decline (Figure 4.5) but persist in grassland habitats around the state, including on some lands enrolled in agricultural programs such as the Conservation Reserve Program (Sample and Mossman 2008).

Temple and Cary (2008) analyzed statewide bird data over the last 55 years in Wisconsin. Shifts in species richness have been small compared with shifts in relative abundance of species within communities. The prairie bird community decreased the most in species richness (17% of species) primarily from a reduction of grassland habitats, while the oak opening bird community increased 13% in species richness because previously open habitats became progressively invaded by woody vegetation that attracted more woodland birds. Overall, species richness increased slightly within most bird communities. Species such as Carolina Wren (*Thryothorus ludovicianus*), Tufted Titmouse (*Baeolophus bicolor*), and House Finch (*Carpodacus mexicanus*) expanded their range into the state. Other species, such as Wild Turkey, Trumpeter Swan, and Whooping Crane, were reintroduced. Double-crested Cormorant, Sandhill Crane, and Cooper's Hawk (*Accipiter cooperii*) populations increased and expanded their range. There have been no extinctions of any bird species in the state since the Passenger Pigeon went extinct in 1914.

Based on North American Breeding Bird Survey data since 1966, species abundance has declined in Wisconsin by 25% for some of the birds monitored by this survey (e.g., the Red-headed Woodpecker [*Melanerpes erythrocephalus*],

Sandhill cranes (Grus canadensis). *This species has increased in numbers in recent decades and expanded its range. Photo by Brian Collins.*

Eastern Bluebird (Sialia sialis) *with food. A bird of open habitats that nests in cavities, this species has been the focus of very successful restoration efforts in Wisconsin. Thousands of artificial nest boxes are built and monitored mostly by volunteer citizens. Photo by Brian Collins.*

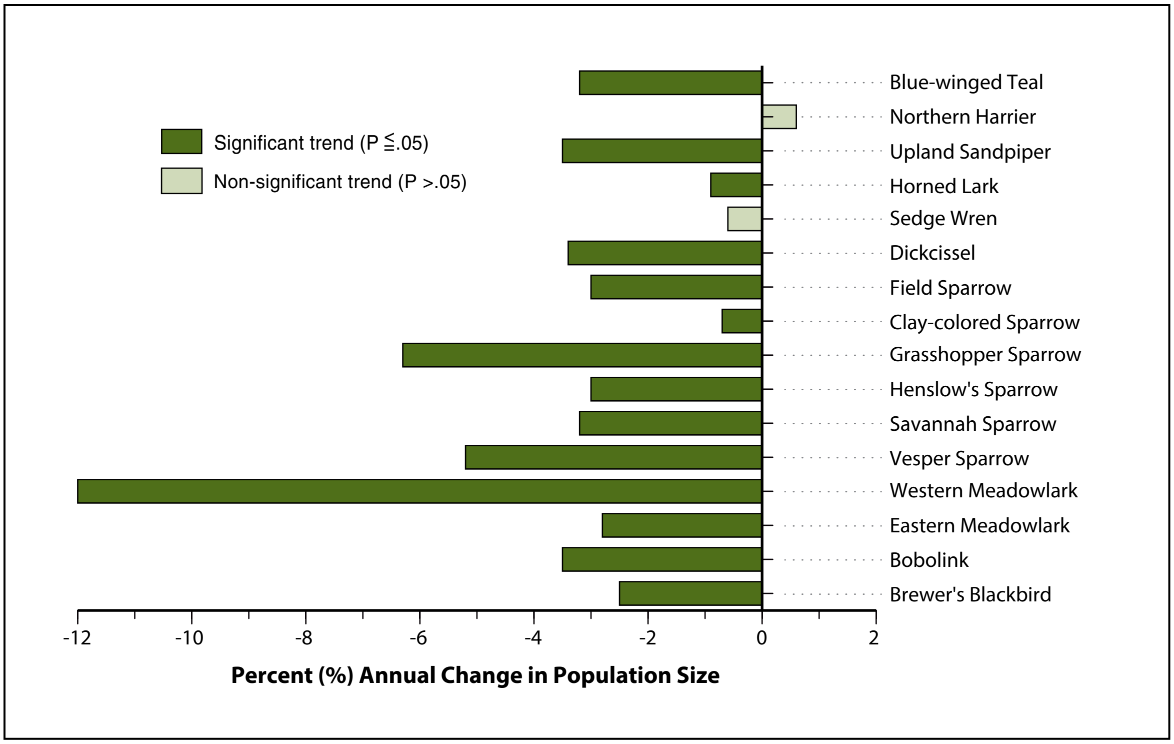


Figure 4.5. *Population trends of grassland bird species of management concern in Wisconsin. Data are from federal Breeding Bird Survey (BBS) routes in Wisconsin, 1966–2010 (Sauer et al. 2011). This figure includes only the 16 species for which Wisconsin BBS data are adequate (adequacy is based on several factors, including sample size and average abundance per route). Figure reproduced and updated from Sample and Mossman 1997.*

the Western Meadowlark [*Sturnella neglecta*], and the Grasshopper Sparrow [*Ammodramus savannarum*]); has stayed the same for 40% of the species; and has increased for 35% of the species monitored (e.g., Canada Goose, Sandhill Crane, and House Finch) (Temple and Cary 2008). Notable declines have occurred for many species of grassland birds.

Amphibians and Reptiles (Casper 2008)

Loss of forests, most of the savannas and prairies, and almost half of the wetlands have dramatically affected reptile and amphibian populations after Euro-American settlement. The losses were greatest and most permanent in southern Wisconsin where prairies and savannas were converted to agriculture and urban use. Changes in northern Wisconsin were less severe as widespread reforestation occurred after large-scale logging, wildfires, and failed attempts at agriculture. Amphibian and reptile populations are especially susceptible to decline because many species require several different habitat types to complete their life cycle. When modifications and barriers on the landscape (e.g., roads, agricultural fields, and urban areas) prevent them from moving between patches of suitable habitat, populations will not persist. Current threats include urban sprawl, shoreline development, habitat loss and degradation, pollution, invasive species, and climate change.

Because data over time are lacking for this group of animals, Casper (2008) illustrated changes in amphibian and reptile communities by using two extreme examples: one from an undisturbed site in northern Wisconsin (the Apostles Islands) and one from a highly altered landscape in southeastern Wisconsin (Milwaukee County). The Apostle Islands sites still support most of the species that were likely present prior to Euro-American settlement. The Milwaukee County sites have lost many of their original reptile and amphibian species, with salamanders losing the most species, followed by snakes, frogs and toads, and turtles. Species diversity and species abundance have both declined in Milwaukee County.

The range of some species has contracted greatly since Euro-American settlement. The eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) was once found in suitable wetland habitats throughout southern Wisconsin. Now it can only be found in a few localities in the state. Northern cricket frog (*Acris crepitans*) was widespread throughout southern Wisconsin but declined rapidly after 1950. Now it can be found in only a few locations in the southwestern part of the state. The queen snake (*Regina septemvittata*) has also disappeared from most of its southeastern Wisconsin range. A suite of prairie and barrens reptiles is still declining, for example, ornate box turtle (*Terrapene ornata*), six-lined racerunner (*Aspidoscelis sexlineata*), western slender glass lizard (*Ophisaurus attenuatus*), North American racer (*Coluber constrictor*), and gophersnake (*Pituophis catenifer*) as habitat becomes more degraded, scarce, and isolated. A 20-year statewide survey of frogs and toads indicated that the northern leopard frog (*Lithobates pipiens*) and pickerel frog (*Lithobates palustris*) are declining (Bergeson and Kitchell 2008).

Fish

Wisconsin waterways have undergone massive changes since the arrival of Euro-Americans. These changes to aquatic systems were at the scale of the great Cutover of the northern forest in Wisconsin a century ago; however, changes to aquatic resources were less graphic (Waller and Rooney 2008). Conversion of prairie and oak savanna to farmland in southern Wisconsin added sediments and nutrients to the streams, rivers, and lakes. Many rivers and streams were channelized, diked, or dammed to control water, prevent flooding, provide transportation, and generate power. Dams changed the structure and habitat of streams and rivers by creating stagnant pools of water above the dam rather than allowing a free-flowing river. They also imposed barriers to aquatic organisms that moved up and down the rivers. Rivers and streams in northern Wisconsin were used to float logs to the mill, scouring the bottoms and sides of streams and depositing large amounts of bark and other debris on the streambed. Commercial fishing reduced fish populations and changed the predator-prey relationships in large lakes. Lakeshores went from undisturbed to developed with resorts and cottages to intensive residential development accelerating eutrophication and altering littoral zone and shoreline habitats. All these changes impacted the fish communities in Wisconsin.

Lakes Superior and Michigan (Kitchell and Sass 2008)

The rapid influx of European immigrants brought major changes to Lake Superior and Lake Michigan. Although the agents of change (commercial fishing and invasive exotics) were similar in the two lakes, the outcomes were very different. When the Erie and Welland canals were completed around Niagara Falls, the natural barrier between the Atlantic Ocean and the Great Lakes was broken. The sea lamprey appeared in the Great Lakes in the early 20th century and became fully established throughout the Great Lakes. Because of its size and feeding rate, the sea lamprey effectively acts as a predator to kill smaller fish (<3 kg). This invader presented a new mortality agent for local fish that were already being overexploited by commercial fishing. The lake trout was especially affected and was eliminated from four of the five Great Lakes and was greatly reduced in Lake Superior where it remained. Although there have been efforts to restore the lake trout in Lake Michigan, little natural reproduction occurs, and the population persists only through stocking. Although Lake Superior's lake trout population dramatically declined, with the control of the sea lamprey and regulated commercial fishing, the native stocks gradually recovered. However, most of the biomass of lake trout in Lake Superior is now composed of the "siscowet," a fatty variant of the lake trout that inhabits deep water and is undesirable for commercial or sport fishing uses.

Alewife and rainbow smelt are native to the Atlantic Ocean. The alewife entered the Great Lakes through the Erie Canal. The rainbow smelt was purposely introduced into Crystal Lake in Michigan's Lower Peninsula in the 1900s and spread downstream to Lake Michigan. Alewife and rainbow smelt flourished because populations of predatory fish such as lake trout were low, and both species have negatively affected other native forage fishes. The alewife reached exceptionally high levels in Lake Michigan in the 1960s and depleted the zooplankton community. The rainbow smelt population in Lake Michigan was suppressed by the abundant alewife population. When the zooplankton population was depleted, the alewife population crashed, with dead alewives clogging municipal water intakes and littering the beaches. In Lake Superior, the rainbow smelt replaced native cisco species as the dominant predator of zooplankton. As lake trout recovered in Lake Superior, it lowered the rainbow smelt population and allowed native ciscoes to again recover.

In Lake Michigan, the loss of the lake trout and other native fish allowed exotics to become abundant, creating profound ecological consequences. To control these nuisance species, Pacific salmon were introduced. The hope was to use Pacific salmon as a biological control agent for the alewife and provide a sport fishery to replace the nonreproducing native lake trout. At first this worked, reducing the alewife population to half its former abundance and allowing other native fish species such as deepwater cisco and some sculpin species to recover. The zooplankton community structure returned to dominance by a large ***Daphnia*** (*Daphnia* spp.)**,** and water clarity increased twofold. Pacific salmon were also stocked in Lake Superior to control rainbow smelt, but stocking levels were much lower. Stocking levels of nonnative salmon were above what the prey base could support, due to pressure from anglers wanting more fish. In the 1980s, dead and dying salmon started appearing on the beaches. Intensive salmon raising practices promoted the development of a bacterial kidney disease. This disease killed many salmon already stressed by an insufficient food source (the alewife). Stocking levels were reduced to establish an equilibrium between alewife and salmon populations.

Other exotics arrived and began affecting the lower parts of the food web in Lake Michigan. Zebra mussel and quagga mussel (*Dreissena bugensis*) were both released from ballast water into the Great Lakes. They both consume large amounts of phytoplankton and small zooplankton and are only limited by habitat productivity, temperature, and the amount of calcium needed for their shells. The lack of calcium limits their extent in Lake Superior, but they do occur in some shallow productive bays. Zebra mussels are having a great affect on Lake Michigan, increasing the water clarity and allowing submergent vegetation to thrive that favors other exotics such as the round goby, which is now replacing other native ***benthic*** fishes. The quagga mussel inhabits deeper water habitats and has caused a large decline in the benthic amphipod, *Diporeia hoyi,* which is a major food item for many fishes. To date, it is unknown what effect this will have on the ecosystem.

One concern for the future of Lake Michigan is that the Chinook salmon (*Oncorhynchus tschawytscha*) is now reproducing in local streams, increasing the size of the predator population. This could lead to the collapse of the alewife population at a time when zebra and quagga mussels are dramatically altering the benthic environment and eliminating important food resources for some native fish. However, native yellow perch (*Perca flavescens*) and walleye (*Sander vitreus*) are having remarkable recruitment success, reflecting reduced alewife interactions. It is unclear where the system may go with the introduction of additional exotic species.

Despite similar forces that have disrupted their ecosystems (exotics and overfishing), the resulting impacts to the two lakes are quite different. The Lake Michigan fishery is now a salmon-dominated system, marked by some successes of restoring native species. It is still plagued with exotic species, and where the system will go with the introduction of additional exotic species is still unknown. Lake Superior reflects the success of restoring many of its native fish but is still under threats from exotic species.

Nongame Fish in Southern Wisconsin (Marshall and Lyons 2008)

Wisconsin has 147 native species of fish; however, most are ***nongame*** fishes that receive little attention. The occurrence and abundance of many sensitive nongame species declined after Euro-American settlement. A comparison of the results from fish surveys in the late 1970s and the 2000s shows a continued decline of these sensitive fish. Small streams with their limited volumes of water are especially susceptible to environmental degradation. Fish species richness declined by 70% in streams sampled from the 1970s and again in the 2000s. Shifts in land use, especially urbanization and intensification of agriculture, were the main reasons for these declines.

There were also dramatic declines in native fish species richness in lakes in southern Wisconsin over the same 30-year period. Sensitive fish species richness dropped by 85% from the 1970s to the 2000s. Many of the sensitive species that disappeared have a strong affinity for aquatic vegetation and may reflect changes in near-shore habitat from shoreline development, such as house construction, beach development, and installation of docks and piers.

Conservation of these sensitive fish species in southern Wisconsin may require a network of "safe havens" that are protected from certain types of agriculture and urban land uses to provide habitat for these species.

Invertebrates

Mussels (Lisie Kitchel, Wisconsin DNR, personal communication)

Wisconsin's mussel populations are part of the Upper Mississippi River fauna, which is one of the areas of high mussel diversity and abundance in North America and is globally important for that reason. Significant changes in Wisconsin's rivers and streams since Euro-American settlement have resulted in dramatic declines in native freshwater mussel populations. The majority of mussels have declined in both species diversity and abundance over the last one to two hundred years. In the U.S., up to 70% of the freshwater mussel species remaining are listed as threatened, endangered, or rare, and some are extinct.

Mussels were abundant and important to American Indians who used them for food, tools, and decoration. The meat from mussels was often smoked and eaten like jerky. The shells were used for scrapers, cutting and cooking utensils, hoes, fishhooks and lures, and jewelry.

A comparison of archeological and present-day mussels has found that the size of mussels has increased in modern times (A.E. Bogan, North Carolina Museum of Natural Sciences, personal communication). Historically, native mussels were so abundant in some rivers that they were competing for food and were stunted. Today, the average size of any one individual mussel is larger; however, there are not nearly as many mussels or mussel species left.

Mussels are important ecologically because of their ability to filter the water, helping to maintain water quality as well as remove and concentrate contaminants. Their presence in streams increases the diversity of other aquatic invertebrates (insects, crayfish, and snails) by both providing food (pseudofeces) and habitat (shells and ***bioturbation*** of the substrate). Mussels also provide a direct food source for some mammals, birds, and fish species.

Mussels have declined locally and globally due to loss of water quality, water quantity, and habitat alteration. Some species are now extinct, and other species have been extirpated from a geographic area. These losses may have been the result of direct impacts to the mussels themselves or indirect impacts from the loss of their host fish (required to complete their life cycle), and subsequent loss of reproduction. The tolerant species have adapted, and some have even expanded their range and numbers. That may be a function of being "generalists," or their host is more tolerant of current conditions. Mussel species that use minnows as their host and can use carp (a nonnative ***cyprinid***) as a host may be more abundant and widespread due to the shear abundance and movements of this nonnative host.

One of the biggest factors in the decline of mussel populations is deteriorating water quality. This occurs from siltation, pollution, or chemicals in the water that affect their reproduction, causing them to abort, eroding their shells, causing disease outbreaks, or stressing them. Water quality can be directly linked to land use and what is put in the water directly or indirectly. Water quality also affects fish hosts, so if a fish host cannot survive, the mussel species dependent on them for reproduction will also not survive.

Alteration of habitat in streams by channelization, gravel dredging in rivers, and dams is another cause for decline. Dams not only impose barriers to host fish but also alter the entire aquatic system from a flowing water system to more lake-like water above the dam. Wisconsin's native mussels evolved in flowing water systems and rely on running water to breath, remove wastes, and reproduce. These same factors can also affect host fish. Reservoirs behind dams also serve as good habitat for zebra mussels and other exotics to thrive in and then invade downstream ***river reaches***, causing a continual stressor for native mussels.

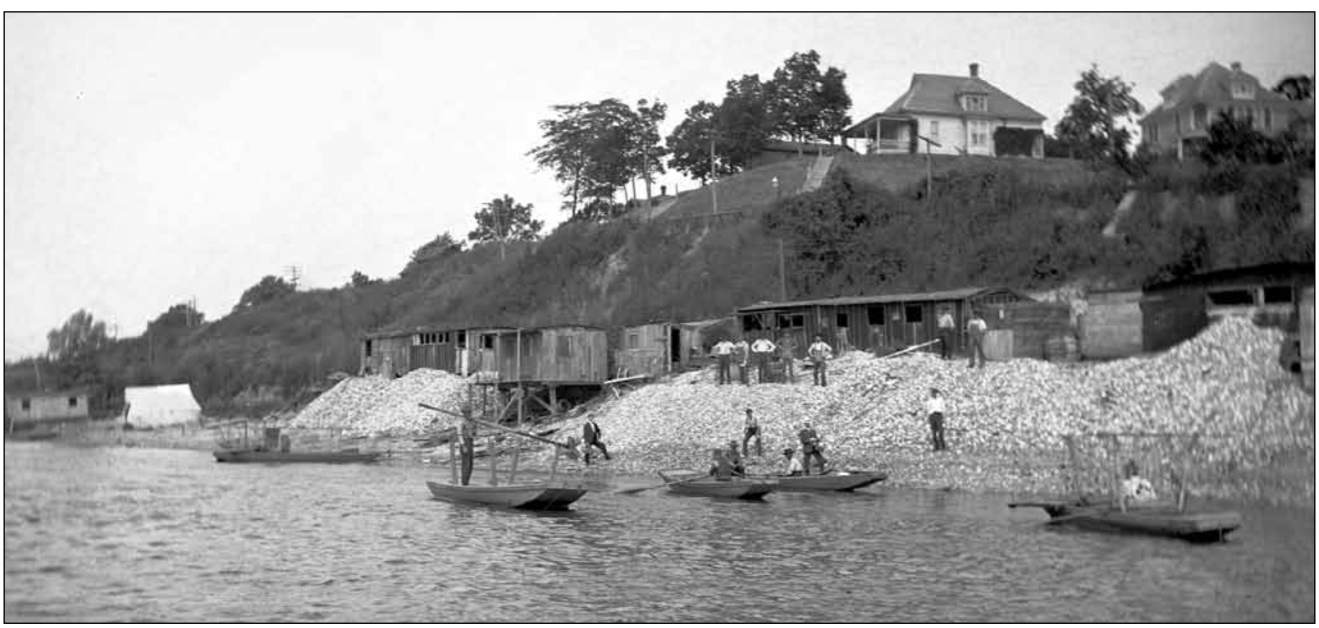
Overexploitation has affected mussel populations locally and regionally. There was the "pearl rush" of the 1800s when people went to streams and opened mussels to look for pearls, which reduced mussel populations. Commercial use of mussel shells for pearl buttons caused overexploitation of mussel populations since there were no limits on the size of the shell that could be taken, the season when they could be harvested, or the quantity of mussels that could be taken. After World War II, plastic provided cheaper buttons, and the pearl button industry declined. Since the 1960s, commercial use of mussel shells has been for nuclei of cultured pearls. However, mussels were being overharvested, and Wisconsin and other states closed their commercial harvest of mussels because commercial harvesters had been taking small mussels before they could reproduce.

Invasion by nonnative mussels is yet another factor that has changed the native fauna. This is especially a concern if native mussel populations are at a low level with a low reproductive rate. Some native mussels have been able to hang on in running water systems in the face of exotic, invasive mussels such as zebra and quagga mussels. Impacts from zebra mussels have been far greater in the big rivers of Wisconsin (where the highest mussel diversity is) than in the small streams. To date, exotic invasive mussels may have reduced the number of native mussels in many rivers, but the native species are still present, and some appear to be reproducing. It is possible that an equilibrium has not yet occurred between native and invasive mussels.

Conservation of mussel populations includes protecting water quality and quantity and the physical habitat of streams for both mussels and their fish hosts. Preventing the spread of invasive mussel species and eliminating siltation or contaminants into water systems will help, and attention should also be paid to compounds like estrogens in the water, which can affect mussel reproduction. Another threat is on the horizon from an exotic invasive fish species that is a molluscavore, the black carp (*Mylopharyngodon piceus*). Preventing invasive molluscavore species from invading Wisconsin waters will be important. Laws intended to improve water quality will help with mussel conservation, but they are only as good as their enforcement and implementation. An important point to remember is that mussels cannot complete their life cycle without a host species, so any consideration of conservation of mussels needs to include the health of the host population, and there are mussel species for which the host is still unknown. Techniques to propagate mussels are being developed. Some mussel species have been easily propagated, but knowing the host fish species is critical before propagation can be attempted.

Butterflies and Moths (Ferge 2008)

Butterfly and moth species, which belong to the insect order Lepidoptera, can be highly sensitive to changes in the environment. Most Lepidoptera species prefer a specific habitat type. Some depend on a single plant species during their larval stage. Many of the plants and habitats that supported sensitive Lepidoptera are now threatened because of habitat loss,



Mountains of shells rose up alongside the Mississippi as clammers made a living harvesting mussels to supply to the button industry. Source: Oscar Grossheim Photo Collection, Musser Public Library, Muscatine, Iowa. Permission granted by Musser Public Library.

fragmentation, degradation, and isolation. Loss of habitat is often reflected in diminished populations. Besides habitat loss, other causes of Lepidoptera population declines include selective grazing or browsing on larval food plants by species such as white-tailed deer, rendering the habitat unsuitable for some specialized Lepidoptera. In many areas, invasive plants are displacing the native plants used by Lepidoptera species. An example is when reed canary grass invades a sedge meadow and displaces the native vegetation. Lepidoptera species such as mulberry wing skipper (*Poanes massasoit*), broad-winged skipper (*Poanes viator*), dion skipper (*Euphyes dion*), black dash skipper (*Euphyes conspicua*), two-spotted skipper (*Euphyes bimacula*), Acadian hairstreak (*Satyrium acadica*), Baltimore checkerspot (*Euphydryas phaeton*), and eyed brown (*Satyrodes eurydice eurydice*) can no longer maintain their populations there. Garlic mustard (*Alliaria petiolata*) is another invasive species that outcompetes and can replace native plants. Two Lepidoptera species (mustard white [*Pieris napi*] and West Virginia white [*Pieris virginiensis*]) are especially affected. Garlic mustard attracts these two species, which lay their eggs on this plant, but the larvae cannot survive on a diet of garlic mustard and die, resulting in a population decline.

There are few historical baseline data from which to measure changes in Lepidoptera communities in Wisconsin. Museum specimens from Wisconsin are lacking before 1945 (Ferge 2008). However, some significant changes in range have been documented fairly recently. The greenish blue butterfly (*Plebejus saepiolus*) was common from Door to Sawyer counties from 1920 to 1940. Today, it is found in only a few localities in Forest and Bayfield counties. In the 1960s, the common ringlet (*Coenonympha tullia*) was found only in Burnett and Douglas counties; it is now found all the way from Lake Superior to La Crosse County.

The rare West Virginia white butterfly on large-flowered bellwort (Uvularia grandiflora), *a native lily of rich mesic forests. The larvae feed exclusively on toothworts (*Dentaria *spp.), which can be outcompeted by garlic mustard, a nonnative invasive plant. Photo by Mike Reese.*

Based on habitat change and destruction, losses of native butterflies and moths have been most severe in southern Wisconsin. Except for scattered remnants of native vegetation, much of southern Wisconsin is an agricultural landscape that supports only Lepidoptera that are generalists. Currently, the forested areas of central and northern Wisconsin support the most diverse Lepidoptera communities. However, many of Wisconsin's rarest butterflies and moths are strongly associated with remnant prairies, savannas, and wetlands (e.g., good quality natural communities).

Individual Species Changes

At the time of Euro-American settlement, northern Wisconsin was historically important for many wildlife species, especially forest, wetland, and barrens birds, and large, wide-ranging forest mammals. It was particularly important for moose, white-tailed deer, black bear, gray wolf, fisher, American marten, bobcat, beaver, and river otter (*Lutra canadensis*). Neotropical migrant birds and forest raptors were important as were Bald Eagles, Osprey, Common Loon (*Gavia immer*), Trumpeter Swan, Spruce Grouse (*Falcipennis canadensis*), and Sharp-tailed Grouse (*Tympanuchus phasianellus*). Along the Great Lakes shorelines, species such as gulls, terns, cormorants, and other waterbirds were important. Northern Wisconsin forests were logged in the late 19th and early 20th century, and in the barrens and prairie areas of northwestern Wisconsin, fires were suppressed. The prairies and pine barrens converted to jack pine and oak forests while some areas were converted to farms. As these modifications took place across the landscape, wildlife populations changed.

Southern Wisconsin was especially important historically for wildlife species that used prairies, oak savannas, marshes and sedge meadows, oak forests, maple-basswood and maple-beech forests, bottomland hardwoods, rivers, lakes, and streams. This area of the state was particularly important for elk, American bison, white-tailed deer, gray wolf, cougar, Wild Turkey, Sharp-tailed Grouse, Greater Prairie-Chicken, Passenger Pigeon, Trumpeter Swan, Northern Bobwhite, timber rattlesnake (*Crotalus horridus*), eastern massasauga rattlesnake, and the complex of predators that preyed upon them. In the mid-19th century, when the southern Wisconsin landscape was settled by Euro-Americans, large-scale wildfires were reduced in frequency and extent of area affected. Prairies and savannas were plowed and forests cleared to accommodate agricultural uses. Wildfires were suppressed and controlled, allowing savannas and prairies to convert to woodland and forest. Forests were grazed by livestock, which altered and sometimes destroyed native understory vegetation. These landscape modifications resulted in major changes to wildlife populations.

Extinct Species

Passenger pigeon

Although the distribution of the Passenger Pigeon has been described as covering the eastern half of North America (Schorger 1946), nesting was limited by the presence and abundance of mast (primarily beech nuts and acorns). Schorger (1946) reported from newspaper accounts and interviews that the Passenger Pigeon nested by the millions in Wisconsin. They likely nested over much of southern Wisconsin, where mast was available. Passenger Pigeons were shot and trapped during the nesting season, and squabs were taken from nests and shipped to markets in Milwaukee, Chicago, and cities on the East Coast by the trainload (Schorger 1937a). The Passenger Pigeon was thought to only lay one egg each year, only nested in communal roosts, and was dependent on abundant mast for nest production, so the heavy kill of the Passenger Pigeon led to its extinction (Schorger 1937a).

With a large presence of oaks, central Wisconsin was undoubtedly an important nesting area for the Passenger Pigeon during years of high mast production. There are many historical references to the Passenger Pigeon in the area around Kilbourn (Wisconsin Dells) (Schorger 1937a). In 1871, one of the largest recorded nesting attempts of the Passenger Pigeon occurred in the ***scrub oaks*** of central Wisconsin. The nesting area covered 544,000 acres and was estimated to contain 136,000,000 Passenger Pigeons (Figure 4.6). In 1877 a small nesting took place in Marquette County. A Mr. Reynolds told author A.W. Schorger that prior to 1882 "millions and millions of birds left the nesting areas north of Kilbourn and that he was never satisfied as to where they went" (Schorger 1946). After 1882 a noticeable decline of the Passenger Pigeon was noted in Wisconsin. An attempted nesting occurred near Wautoma in 1887 but was broken up by shooting (Schorger 1946). It was the last recorded attempt at mass nesting in the state. In 1890 several thousand pigeons appeared near Briggsville and Wautoma and several other places in the state. Populations continued to decline with few sightings in Wisconsin during the late 1890s. The year 1899 is considered to be the last year there was a wild Passenger Pigeon in Wisconsin. The last known Passenger Pigeon died in 1914 at the Cincinnati Zoo, and the species was then extinct.

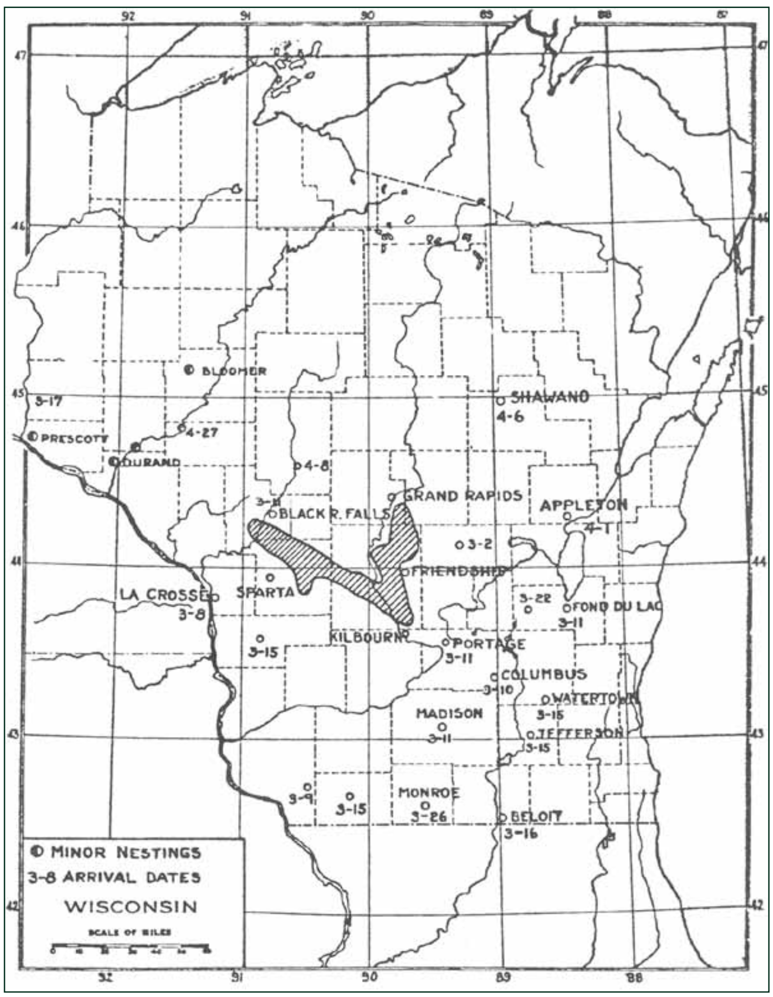


Figure 4.6. *Location and extent of Wisconsin Passenger Pigeon nesting in 1871. Figure reproduced from Schorger (1937a) by permission of the Linnaean Society of New York.*

Extirpated Species

Some species were eliminated from the state but did not go extinct. A discussion of some of these extirpated species follows.

American Bison

Prior to Euro-American settlement, American bison occupied the prairie and oak savanna areas of the southern and western parts of the state

Illustration of female Passenger Pigeon by Charles O. Whitman (Whitman 1919).

(Figure 4.7). American bison occurred from Racine along Lake Michigan, north to Lake Winnebago, and west to Burnett County on the St. Croix River. Bison were more frequently reported to the west and northwest of Lake Michigan. There are many historical accounts of American bison west of Lake Winnebago. An early settler, William Powell, stated that the Buffalo Lake region (Marquette County) was a great bison range in the very early 1800s (Schorger 1937b). American bison were likely abundant in western Wisconsin. In his account of the historical range of the bison in Wisconsin, Schorger (1937b) noted that bison ranged eastward of the St. Croix River; he recorded Henry Schoolcraft's 1831 account of "the prairie country" that extended into the vicinity of Rice Lake and in scattered patches along the Red Cedar River. Schorger (1937b) mentioned both the Wisconsin and Chippewa River valleys as having abundant bison populations. Records of American bison occurring in the extreme southwestern part of the state are from Prairie du Chien and Blue Mounds, where habitat was suitable for their occurrence. A map of southwestern Wisconsin published in 1829 noted that "not more than a tenth is covered by timber in detached groves, the remainder being prairies" (Schorger 1937b), indicating that suitable habitat was once present. In *First Annual Report on the Geological Survey of the State of Wisconsin*, Edward Daniels (1854) estimated that only one-third of southwestern Wisconsin was prairie in 1854. He attributed this rapid change from prairie to timber to the cessation of fires and rapid growth of young trees on the open prairie. One problem is that there are no written records for extreme southern Wisconsin before 1800, and bison populations could have been greatly reduced by the time of more recent reports.

Current theories about historical American bison population numbers in Wisconsin are that American bison preferred short- to mid-grass prairies and were prevented from moving east of the Mississippi River by hunting pressure from American Indians (Martin and Szuter 2002). For a couple of centuries (1600–1700s), American Indian populations declined from disease and social disruption upon, and even before, the arrival of Euro-Americans (Diamond 1997, Mann 2005). During that time, American bison populations increased and expanded. As American Indian tribes were forced westward from near-Atlantic areas by Euro-American settlers, the American bison population in Wisconsin

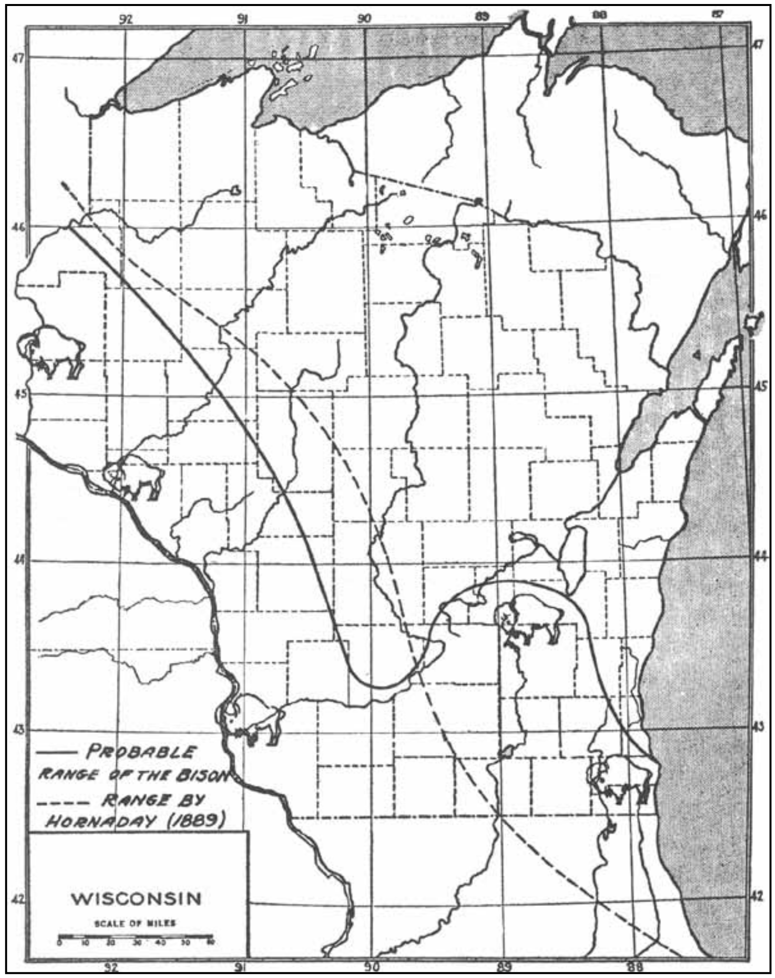


Figure 4.7. *Probable range of the bison in Wisconsin prior to Euro-American settlement. Figure reproduced from Schorger (1937b) by permission of the Wisconsin Academy of Sciences, Arts and Letters.*

American bison survive in large preserves in the West, in zoos, and on ranches where they are raised for meat. Photo by Wisconsin DNR staff.

came under heavy hunting pressure by the tribes for food. The American bison population had been reduced to small numbers before the state was settled. The last two American bison that were shot east of the Mississippi River were shot near the Trempealeau River in 1832 (Schorger 1937b).

Caribou

Caribou (*Rangifer tarandus*) were never common in Wisconsin, but there are a few records from lands bordering the southern shores of Lake Superior. Most of these reports were from the Keweenaw Peninsula in Upper Michigan (Schorger 1942a). However, there is a report of hunters killing caribou in Wisconsin in 1910, but those records are questionable. Bones of caribou have been found as far south as Polk County (Schorger 1942a), and there are some records from northwestern Wisconsin (Jackson 1961). It is unlikely that caribou were ever abundant in Wisconsin historically because their preferred habitat is muskeg, which is very limited here. In 1906, 20 caribou were moved from Newfoundland to the Pierce estate on the Bois Brule River in Douglas County, but none of them survived (Jackson 1961).

Extirpated Species Again Present in the State

Some species that were eliminated from Wisconsin have been reintroduced or have recolonized the state. Below is a discussion of some of these species.

Elk

Elk bones and antlers have been found throughout Wisconsin (Schorger 1954). But elk flourished before Euro-American settlement in open woodlands, oak openings, and at the border of grasslands and forests. Since elk eat grasses and sedges, they were most numerous and abundant in the southern and western parts of the state (Figure 4.8). Elk occurred in south central and southeastern Wisconsin but declined rapidly after Euro-American settlers began to arrive in the early 1800s. Many elk antlers have been found in lake bottoms and marshes throughout this area (Figure 4.8).

Elk were abundant in the western part of Wisconsin during the early 1800s. Schorger (1954) recorded historical accounts of elk being plentiful on the St. Croix River in 1850 and in the environs of Hudson in 1855. The Chippewa, Kickapoo, Trempealeau, and Mississippi River valleys were often mentioned as having abundant elk populations. An early pioneer named Holman settled at Platteville and reported that elk and other game were found in "astonishing numbers" in 1828 (Schorger 1954). Elk were still abundant in the western part of the state during the 1850s but declined rapidly after that. The last reliable report of elk in Wisconsin is from west of Menomonie in 1866 (Schorger 1954). Apparently, elk were absent in northern Wisconsin before newspapers could document their extirpation.

Attempts have been made to restore elk in Wisconsin. In 1913 a carload of elk was shipped by rail from Yellowstone National Park to the State Game Farm at Trout Lake (Vilas County). Only two females survived this trip. Later a bull elk was added to the game farm pen, and the herd slowly increased. In 1917 a second shipment of 41 elk was obtained from Jackson Hole, Wyoming (Schorger 1954). About half of the elk died immediately following shipment. The remaining elk were held in a pen at Trout Lake until 1932. By 1932 only 15 elk were left in the pen, and they were released into the wild. These elk remained in the Vilas County-Oneida County area, but the population declined due to poaching. By 1954 elk numbers were believed to have been reduced to two animals. The population subsequently disappeared due to illegal hunting and other causes.

In May 1995, elk were reintroduced into Wisconsin. Three bulls, 11 cows, and 11 young elk were moved from an elk herd near Gaylord, Michigan, and released in the Clam Lake area (Ashland County). The elk reintroduction site was centered around clearings made for the U.S. Navy's Extra Low

Long-billed Curlew (Numenius americanus). *Photo by Robert Burton, courtesy of U.S. Fish and Wildlife Service.*

Woodland caribou grazing. Photo by Erwin and Peggy Bauer, courtesy of U.S. Fish and Wildlife Service.

Frequency (ELF) radio transmission lines. These openings provide valuable habitat to grazing elk. These animals have been tracked with radio transmitters to follow their survival. In 2012, Wisconsin had about 150 elk, all of them in the Clam Lake area.

Moose

Moose were once fairly common in Wisconsin, found throughout the northern third of the state, with reports of moose as far south as the Lake Winnebago area and one report each from Green Lake County and Sauk County (Schorger 1956). The largest moose population was in the northwestern part of the state (Figure 4.9) because of its abundant wetlands, especially shallow lakes and shrubby wetlands, which provided good foraging areas. Schorger (1956) described a historical account in which moose is mentioned as one of the principal game animals of the American Indian tribes in the Lake Superior area in 1820. Due to uncontrolled hunting, the moose had become rare in much of the state by 1866 (Schorger 1956). However, moose seemed to persist in the northwestern part of the state. In the fall and winter of 1884, it was reported that "a hunter had exceptional success in killing five moose in Douglas County" (Schorger 1956). After 1900, few moose existed in the state. In the 1960s, moose were again seen in northwestern Wisconsin as the Minnesota moose population increased. Today there are a small number of moose in the state; estimates range from 20 to 40 animals, depending on the year. Most moose wander into Wisconsin from Michigan and Minnesota. A calf was born in Florence County in the summer of 2008, but it is unclear if Wisconsin has a self-sustaining moose population. Moose do not survive well in areas with high populations of white-tailed deer. Deer are often infected with a brain parasite that doesn't harm the deer but is lethal to moose. In all, there have been more than 280 observations of moose reported over the last decade. In 2012 there were 34 moose sightings in Wisconsin, but some may have been repeat sightings of the same animal.

Gray Wolf

The gray wolf was found throughout the wooded regions of Wisconsin and was common in the prairie regions as well (Schorger 1942a). After Euro-American settlement, the gray wolf population declined dramatically, especially in southern Wisconsin, due to a reduction in food resources (deer and rabbits), indiscriminate shooting, and

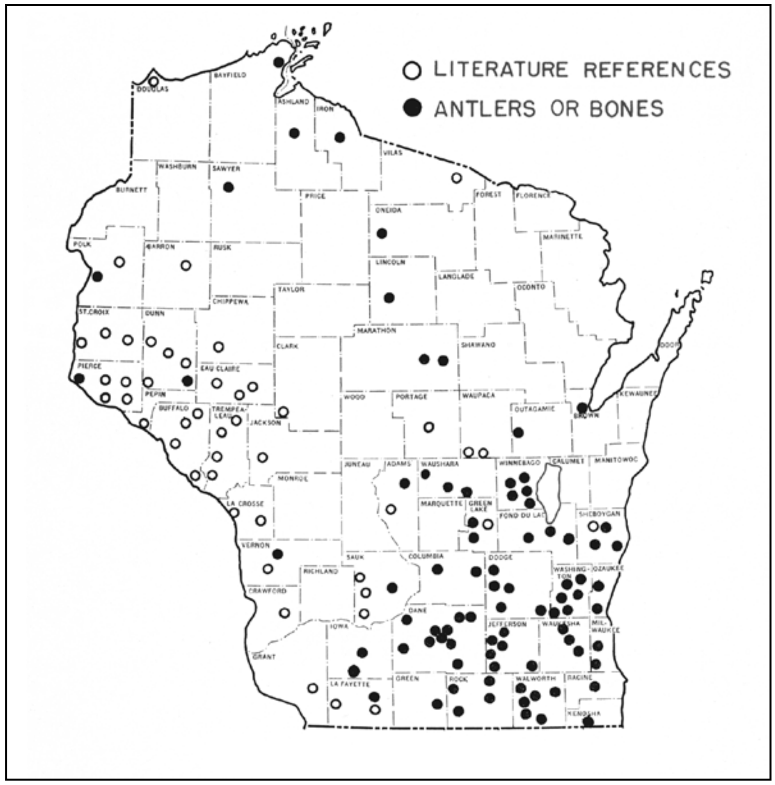


Figure 4.8. *Historical records of elk in Wisconsin. Figure reproduced from Schorger (1954) by permission of the Wisconsin Academy of Sciences, Arts and Letters.*

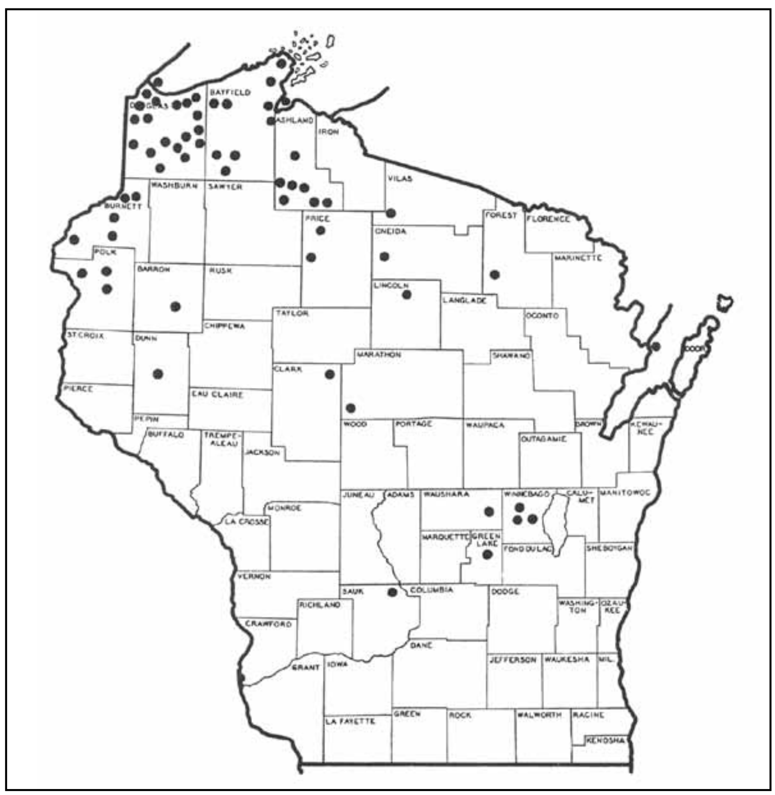


Figure 4.9. *Historical records of moose in Wisconsin. Figure reproduced from Schorger (1956) by permission of the Wisconsin Academy of Sciences, Arts and Letters.*

bounties. By the 1920s, gray wolf populations only remained in the more remote portions of northern Wisconsin (Thiel 1993). Gray wolf populations continued to decline in northern Wisconsin until 1958 when the last Wisconsin gray wolf was thought to have been killed by a car in Bayfield County. Occasional sightings of gray wolves occurred throughout the 1960s and 1970s, but they were thought to be lone wolves that wandered into Wisconsin from Minnesota or Michigan. Not until the mid to late 1970s was it determined that gray wolves had again become established and were breeding in Wisconsin (Thiel and Welch 1981, Wydeven et al. 2009). Gray wolves continued to emigrate from Minnesota during the next couple of decades. The Wisconsin population had increased to a winter population of about 700 individuals in 2010 (Wisconsin DNR data, Figures 4.10 and 4.11).

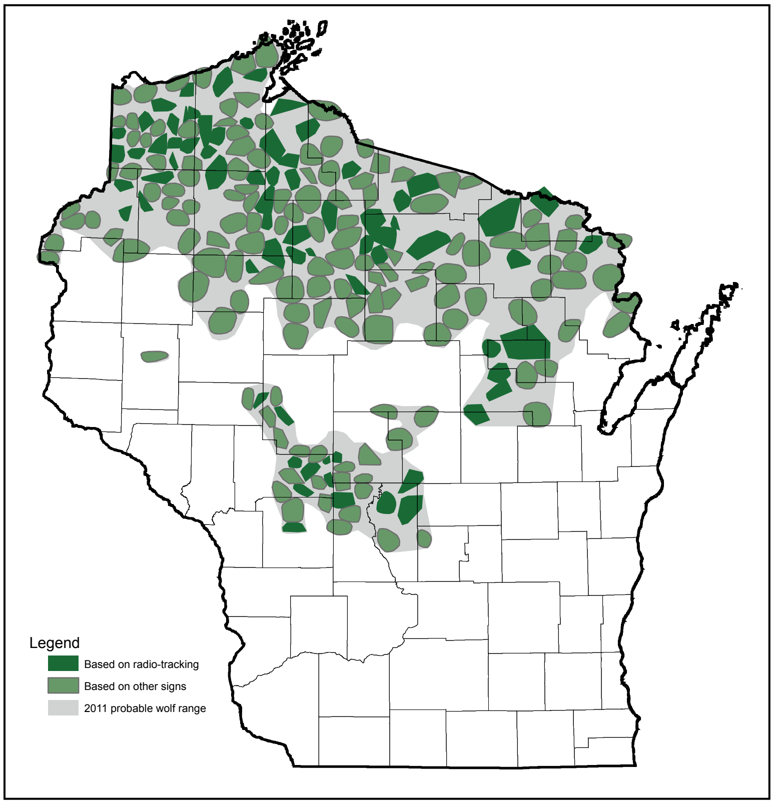


Figure 4.10. *Gray wolf territories in Wisconsin and the probable gray wolf distribution, based on 2011 data from Adrian Wydeven, Wisconsin DNR.*

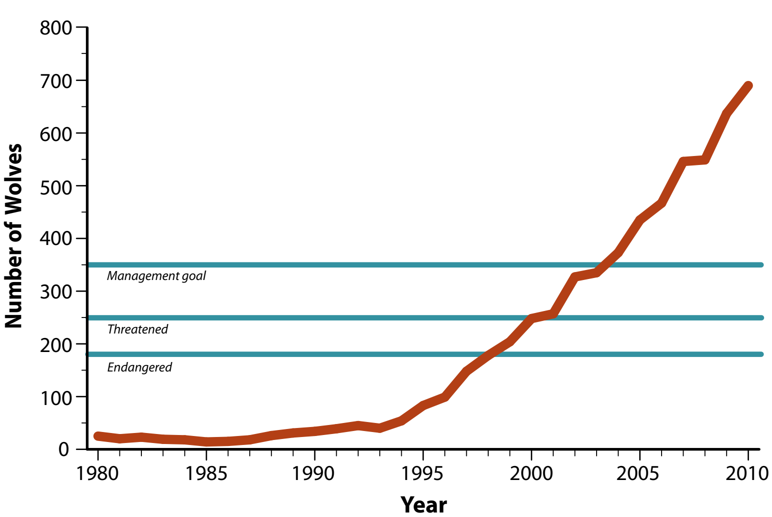


Figure 4.11. *Number of gray wolves in Wisconsin, 1980–2010. Data from Adrian Wydeven, Wisconsin DNR.*

Initial colonization of gray wolves in the region occurred within areas of low road densities in northwestern Wisconsin (Thiel 1985, Mladenoff et al. 1995). This area also had large blocks of unsettled land and availability of white-tailed deer as a food source. From the early 1980s to mid 1990s, northwestern Wisconsin was the stronghold of the gray wolf population in the state. Gray wolf populations there increased and became a source population from which wolves dispersed into other parts of the state. After the mid-1990s, the gray wolf population increased rapidly and dispersed throughout northern and central Wisconsin (Figures 4.10 and 4.11). As gray wolf populations expanded, road density became less important as a factor in habitat selection, and gray wolves seemed to readily spread into areas with extensive forest cover and lack of agricultural land (Mladenoff et al. 2009). Although habitat selection of gray wolves has become more relaxed as the population has spread across the landscape, areas of low road density will continue to serve as core wolf areas (Mladenoff et al. 2009). Large block management that maintain these areas of low road density will continue to help maintain long-term viability of gray wolves in Wisconsin.

Cougar

The cougar was once found throughout the state, but as southern Wisconsin was settled, cougars were shot and trapped until they only occurred in the northern part of the state. As more Euro-Americans moved north, the cougar population was eliminated from that part of the state as well. Wild cougars probably disappeared from the state by about 1910. Reports began to surface in the 1940s of possible cougars in the state. These were probably escaped captive cougars or misidentifications. Wildlife biologists have been collecting reports of cougar observations since the 1940s. Since 1991, the Wisconsin DNR has conducted a standardized system of collecting reports of cougars and other rare mammals. On January 18, 2008, a cougar was sighted near Milton in Rock County. The sighting was verified as a cougar from tracks and DNA obtained from a drop of blood from a cut on its foot. Cougar tracks were later found near Elkhorn (Walworth County), about 23 miles southeast of the Milton sighting, and on April 14, 2008, the same cougar was killed north of Chicago. In early March 2009, cougar tracks were found in northern Washburn County and followed with hounds into Burnett County where the cougar was treed two times (3/4/09 and 3/05/09). Capture attempts were made but were unsuccessful; however, DNA samples were obtained. In May 2009, tracks of a cougar were confirmed in Pepin County, but no DNA was collected. Between early December 2009 and late February 2010, a male cougar was tracked from the northern suburbs of Minneapolis/St. Paul through western Wisconsin and eventually north to Bayfield County. Genetic samples were gathered in St. Croix, Dunn, and Bayfield counties as well as in Minnesota. On December 18, 2009, a male cougar was observed east of Park Falls in Price County, and DNA indicated it was different than the Twin Cities cougar. A cougar was detected on a trail camera on May 20, 2010, near Lena in Oconto County, and six days later, 28 miles to the east, another cougar was seen on a trail camera in Menominee County, Michigan, but DNA samples were not gathered. Thus, from winter 2008 through summer 2010, at least four different individual male cougars were detected in Wisconsin, including the cougar who died in Chicago. The Wisconsin DNR is continuing to investigate sightings and tracks as they occur throughout the state.

American Marten

The American marten occurred in all timbered areas of Minnesota, Wisconsin, and Michigan. It was most frequently found in areas with conifers (Schorger 1942a). The American marten seemed to be more numerous than the fisher based on fur trade records (Schorger 1942a, Wydeven and Pils 2008). The rapid decline of the American marten was caused by an unregulated fur trade and large-scale logging of the forests. The last known historical capture of an American marten was from Maple in Douglas County in 1925. The last recorded historical sighting of an American marten was in Sawyer County in 1939 (Schorger 1942a).

Since then four reintroduction attempts have been made: three in the North Central Forest Ecological Landscape and one in the Apostle Islands. An attempt was made by the Wisconsin Conservation Department (now the Department of Natural Resources) to reintroduce American marten on Stockton Island in 1953, but it was unsuccessful (Wydeven and Pils 2008). The second attempt was by the U.S. Forest Service and Wisconsin DNR, which released 172 marten from Ontario and Colorado into the Nicolet National Forest of northeastern Wisconsin from 1975 to 1983. Only 27 of the 124 marten released the first winter were females, and some appeared to be in poor condition (Kohn and Eckstein 1985). This population has become established and has remained stable in the Nicolet but has not flourished or expanded as a population just across the border in Upper Michigan has. A third reintroduction of American marten was attempted in northwestern Wisconsin in the Chequamegon National Forest in 1987–90. During this time, 139 martens were captured in northern Minnesota and released on the Chequamegon National Forest (Williams et al. 2007). This population has persisted but has been declining. A fourth reintroduction to bolster the Chequamegon marten population took place from 2008 through 2010 when 90 American martens were captured and moved from Minnesota to this area (WDNR 2012). For a detailed account of marten stocking, see Williams et al. (2007). The current Wisconsin distribution of American marten is shown in Figure 4.12.

Fisher

Prior to Euro-American settlement the fisher had a range similar to that of the American marten in northern Wisconsin, but it extended farther south. There are records of fisher as far south as La Crosse, Milwaukee, Jefferson, and Sauk counties. In both La Crosse and Sauk counties, it was

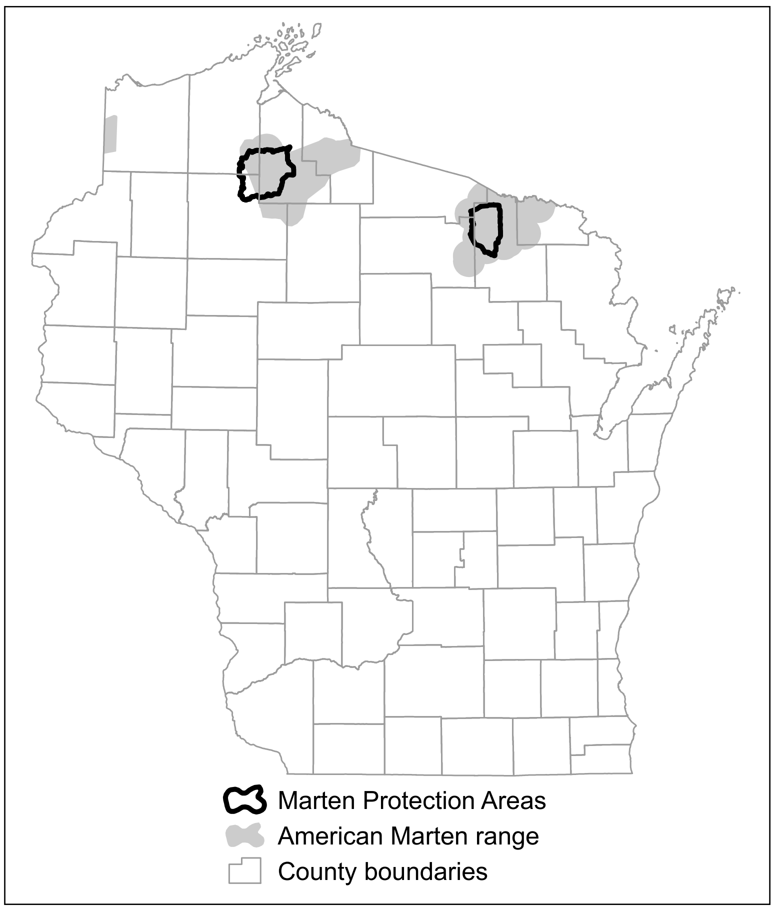


Figure 4.12. *Range of the American marten, 2011.*

described as being numerous. The fisher was not as abundant as the marten and was more common in hardwood forests (Schorger 1942a). Extensive logging, wildfires, and unregulated trapping drastically reduced the fisher population by 1900 (Kohn et al. 1993, Wydeven and Pils 2008). The fisher was given legal protection in 1921, but the population continued to decline. Only three fishers were trapped in the 1920–21 trapping season. The last verified historical report of a fisher was in 1932.

The U.S. Forest Service and Wisconsin Conservation Department cooperated to reestablish a fisher population in Wisconsin during 1956–67. Sixty fishers from New York and Minnesota were released in the Nicolet National Forest from 1956 to 1963, and 60 fishers from Minnesota were released into the Chequamegon National Forest in 1966–67 (Kohn et al. 1993). Peterson et al. (1977) reported that fishers occurred throughout the northern quarter of the state by 1975. For a detailed account of fisher stocking, see Williams et al. (2007). Today the fisher occupies almost all suitable habitats, primarily in the northern and central forested parts of the state. The fisher population was estimated at over 14,000 animals in 2008. The fisher population in the northern forest may have peaked in the 1990s and by 2009 was most abundant along the southern edge of the northern forest in fragmented forest habitat.

Wild Turkey

The historical range of the Wild Turkey was in southern Wisconsin below a line from Green Bay to Prairie du Chien (Schorger 1942b, Figure 4.13). However, since the Wild Turkey reached its northernmost range limits here, the number of turkeys close to this line fluctuated in response to winter severity. Wild Turkeys were most abundant in southern Wisconsin. Schorger (1942b) documented early accounts of the Wild Turkey in Wisconsin: James Lockwood, who settled at Prairie du Chien in 1816, wrote that "it was not an uncommon thing to see a Fox Indian arrive at Prairie du Chien with a hand sled, loaded with twenty to thirty Wild Turkeys for sale, as they were very plentiful about Cassville, and occasionally there were some killed opposite Prairie du Chien." In 1828 Fredrick Hollman settled at Platteville and reported "bear, deer, and wild turkeys being found in astonishing quantities." Another early settler, Andrew Vieau, reported that he took wagonloads of turkeys, venison, and other game from Port Washington to Milwaukee for sale in 1838. As late as 1856, the Wild Turkey was sold in Lancaster for as little as 25 cents each. Due to persistent hunting by settlers for food and for the market, change of habitat, and the severe winter of 1842–43, Wild Turkeys were rare by 1860. The last historical record of Wild Turkey in Wisconsin was the report of one seen in Lafayette County in 1881 (Schorger 1942b).

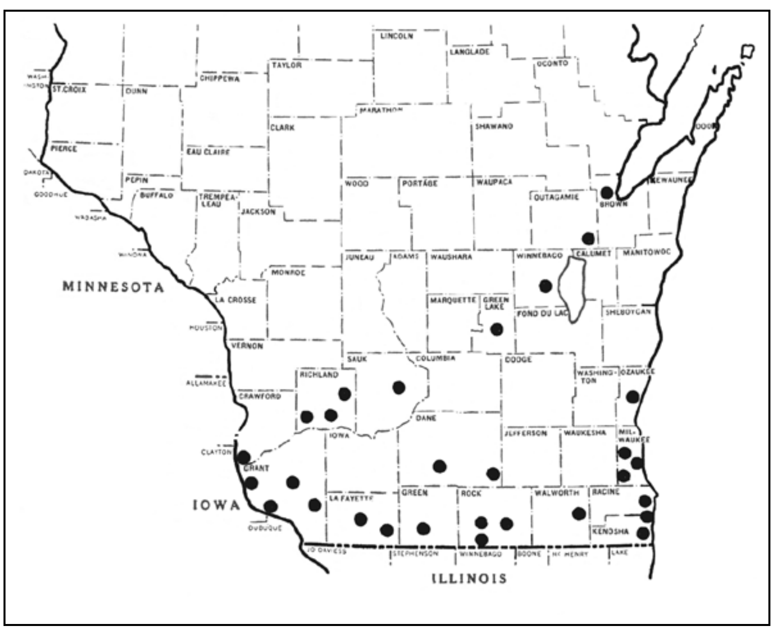


Figure 4.13. *Historical Wild Turkey range in Wisconsin. Figure printed with the written permission of The Wilson Ornithological Society from Schorger, A.W. 1942. The Wild Turkey in early Wisconsin.* Wilson Bulletin *54:173-182.*

There were a number of attempts by private individuals to reintroduce Wild Turkeys into Wisconsin during the late 1800s (Schorger 1942b). These flocks persisted until the early 1900s. Between 1929 and 1939, the State of Wisconsin released about 3,000 pen-reared Wild Turkeys in Grant and Sauk counties (Brown and Vander Zouwen 1993). These birds frequented farmyards and were quite tame. They persisted until 1958 when the last Wild Turkey was reported dead near Grand Marsh (Adams County). In the early 1950s, the Wisconsin Conservation Department stocked Wild Turkeys in the Meadow Valley-Necedah Area. The flock, a cross between game farm hens and wild gobblers, originated in Pennsylvania. During 1954–57, 827 birds from Pennsylvania were released on the Meadow Valley Wildlife Area-Necedah National Wildlife Refuge. Although appearing successful at first, this flock was negatively affected by disease and severe winters. The flock persisted but never expanded its range significantly (Brown and Vander Zouwen 1993). It wasn't until 1976 that the Wild Turkey became reestablished in Wisconsin, when 45 Wild Turkeys trapped in Missouri were released in Vernon County. These Wild Turkeys were obtained in a trade for 135 Ruffed Grouse trapped in southwestern Wisconsin. Other reintroductions followed, and a total of 334 Missouri Wild Turkeys were released in Buffalo, Iowa, Sauk, Trempealeau, Jackson, La Crosse, Vernon, Dane, and Lafayette counties. Once established in these areas, the Wisconsin DNR trapped and relocated Wild Turkeys throughout the state (Brown and Vander Zouwen 1993).

Although the Wild Turkey is now established in every ecological landscape in the state, some of these are well north of its historical range. The

Western Coulees and Ridges and Southwest Savanna Ecological Landscapes have high densities of Wild Turkey and afford excellent hunting and wildlife viewing opportunities.

Trumpeter Swan

The Trumpeter Swan was once fairly common throughout most of the northern United States and Canada. Market hunting and shooting for the millinery trade rapidly depleted nesting populations during the 19th century. Swan skins were sold in the fur trade to Europe where they were used to make ladies' powder puffs, and feathers were used to adorn fashionable hats (WDNR 1997).

In the Midwest, the Trumpeter Swan's historical breeding range reached from western Nebraska to central Michigan and extended as far north and east as James Bay in Canada (WDNR 1997). In Minnesota the species occurred in the prairie and aspen parkland areas of western, central, and northern portions of the state. In Wisconsin the Trumpeter Swan may have nested in all but the northeastern forested regions, most likely in large marshes or shallow lakes. The Trumpeter Swan nested in Minnesota and Wisconsin until the 1880s. By 1900 the Trumpeter Swan was thought to be extinct. Fortunately, a small nonmigratory population survived in the remote mountain valleys of Montana, Idaho, and Wyoming. Later it was determined that there was also a population of several thousand Trumpeter Swans that survived in remote parts of Alaska and Canada. Since then there has been a concerted effort to restore the species.

The Wisconsin DNR began their Trumpeter Swan recovery program in 1987. In 1987 and 1988, Wisconsin attempted to hatch 35 Trumpeter Swan eggs using Mute Swans as foster parents in southeastern Wisconsin. Twenty-six of the eggs hatched, but snapping turtle (*Chelydra serpentina*) predation, possibly mammalian predation, and aggression by an adult male Mute Swan at one nest resulted in only two cygnets surviving to the flight stage. Thereafter, this restoration technique was abandoned. The Trumpeter Swan was listed as Wisconsin Endangered in 1989, and Wisconsin began the first year of an eight-year program to collect Trumpeter Swan eggs in Alaska. From 1989 through 1997, a total of 385 Trumpeter Swan eggs from wild nests in Alaska were collected. They were transported to Wisconsin and hatched in incubators at the Milwaukee County Zoo. Cygnets were placed in one of two release programs. The decoy-rearing program imprinted cygnets on a life-sized decoy after hatching, and they were then released at less than a week of age to marsh sites in northern and central Wisconsin where technicians in camouflaged float tubes led cygnets to feeding and loafing patches. The second release program was the captive-rearing program that maintained cygnets at a site near Pewaukee until they reached two years of age, and they were then released at selected wetland sites in northern Wisconsin. A total of 355 swans were released via these two techniques. These Trumpeter Swans were reintroduced at Crex Meadows Wildlife Area, Sandhill Wildlife Area, and several other areas in the state. Between 1997 and 2007, Wisconsin DNR staff monitored the state's growing flock annually. During this period, more than 50 young were produced each year, and adult survivorship was high. By 2007, 113 breeding pairs occurred in 19 counties. The Trumpeter Swan now nests regularly in the state, and some winter along the lower St. Croix River. By 2008 there were 120 nesting pairs statewide, with over 600 Trumpeter Swans in the Wisconsin population. The species was delisted as a Wisconsin endangered species in 2009.

Whooping Crane

The Whooping Crane likely nested in Wisconsin. Schorger (1964) reported a historical account of Whooping Cranes nesting in Illinois in the early 1700s. Kumlien and Hollister (1903) reported that limited historical records indicate Whooping Cranes may have migrated through Wisconsin and may have been "breeding to some extent." There was an unconfirmed report of a Whooping Crane nest in Brown County, Wisconsin (Carr 1890), and a confirmed report of a nest in Dubuque County, Iowa, adjacent to Grant County, Wisconsin (Allen 1952). There were five reports of Whooping Crane sightings between 1840 and 1850 (Allen 1952), occasional sightings in western Wisconsin, and 12 sightings in southeastern Wisconsin (Hoy 1885). In addition, observations were reported from southwestern Wisconsin on the Mississippi River, a specimen was collected adjacent to the Sugar River in Green County, and there was a sighting in 1884 in Twin Bluffs (Kumlien and Hollister 1903). It is thought that the Whooping Crane was quickly eliminated from the Midwest soon after settlement in the 1850s.

Since 1999, Wisconsin has played a major role in efforts to restore a migratory Whooping Crane population in eastern North America. A core breeding area was established in central Wisconsin at Necedah National Wildlife Refuge.

Whooping Crane. Photo by Ryan Hagerty, U.S. Fish and Wildlife Service.

Necedah National Wildlife Refuge was chosen because of the large number of suitable wetlands as habitat and the controlled access to the National Wildlife Refuge that could prevent human disturbance. As of spring 2011, there were 115 Whooping Cranes in the eastern migratory population, with plans for 25–30 birds to be added to the population each year until it becomes self-sustaining, perhaps by 2020. Two release methods are being used to rebuild the population. Initially, all captive-reared Whooping Crane chicks were conditioned to follow an ultralight aircraft from Necedah National Wildlife Refuge to Chassahowitzka National Wildlife Refuge on the Gulf coast of Florida. These birds then make the return and subsequent migrations south unaided. Beginning in autumn 2005, this program was supplemented with the direct release of Whooping Crane chicks into groups of Whooping or Sandhill Cranes in central Wisconsin. These chicks follow birds that know the migration route from Wisconsin to the southern U.S.

Most birds for which locations are known are in Wisconsin, with an additional two birds in Iowa and single birds located in Indiana, Illinois, and Michigan. At least nine breeding pairs of Whooping Cranes attempted nesting in April 2010, with most of the nests located on Necedah National Wildlife Refuge and one nest on a private cranberry operation. All early nests failed in 2010 due to abandonment; however, three late-season nests and four renests have produced six Whooping Crane chicks on and around Necedah National Wildlife Refuge. The nest abandonment pattern observed in 2010 was similar to what has been observed since 2005. The causes for the abandonment have not been identified, but one theory is that the abundance of biting insects could be a factor; ongoing studies should provide helpful information. In 2010 video surveillance was conducted at all but one Whooping Crane nest, and biting insect data were collected at all failed Whooping Crane nests.

Kirtland's Warbler

The globally imperiled and U.S. Endangered Kirtland's Warbler (*Setophaga kirtlandii,* listed as *Dendroica kirtlandii* on the Wisconsin Natural Heritage Working List; WDNR 2009b) may have been present in Wisconsin prior to Euro-American settlement based on available jack pine habitat. The Kirtland's Warbler nests on the ground under small jack pine from 6 to 15 years old (average tree heights are in the range of less than 10 feet to a little over 16 feet). Reports of male Kirtland's Warblers in Wisconsin have occurred over the last two decades, and it has been nesting in central Wisconsin since at least 2007. At least 15 Kirtland's warbler nesting attempts were observed in 2010 (five were renests) in Adams County. For all of Adams County in 2010, the presence of at least 20 males and 11 females was documented; so far at least nine young have fledged, with at least four nests still active. Brown-headed Cowbird (*Molothrus ater)* parasitism and predation were the main causes of nest loss. One pair of Kirtland's Warblers was present in Marinette County in 2010 but could not be found with later visits. Several male Kirtland's Warblers were seen in Bayfield and Douglas counties in 2010 but have not been seen again. Central Wisconsin and parts of northeastern Wisconsin and northwestern Wisconsin have relatively high potential to provide habitat in which to establish additional breeding populations of the Kirtland's Warbler. The core breeding range of the Kirtland's Warbler is in Lower Michigan, and until very recently, this was thought to be the only place in the world where the Kirtland's Warbler nested.

Kirtland's Warbler, a globally rare species that has been documented breeding in Wisconsin in recent years and is currently the focus of monitoring efforts. Photo by Dean DiTomasso.

Species That Remained in the State

Some species continued to occur in Wisconsin since Euro-American settlement, but their populations changed over time. Below is a discussion of some of these species.

White-Tailed Deer

White-tailed deer were found throughout the state and were more abundant in southern Wisconsin than in the northern part of the state (Schorger 1953) at the time of Euro-American settlement. Northern Wisconsin was primarily mature coniferous-deciduous forest and not optimal habitat, limiting the deer population there. The deer population expanded in northern Wisconsin after large-scale logging took place in the late 1800s (Schorger 1953). The former mature, mixed conifer-hardwood forest in northern Wisconsin was eventually replaced by young deciduous, broad-leaved species, including vast acreages of aspen and white birch and other forage plants that provided an abundant food supply for deer. White-tailed deer herds expanded in the north, but the large number of settlers that followed logging depended partially on venison for food. Following the second "cutover" in the early 1900s, the deer herd expanded dramatically in the north through the 1930s, reaching record densities in the early 1940s (Bersing 1966), but severe winters occasionally kept the deer herd in check.

Deer were reported as plentiful in southern Wisconsin until around 1850 (Schorger 1953). However, as settlers arrived in southern Wisconsin in subsequent years, they depended on venison for food, and as railroads expanded, professional market hunters sent tons of venison to the large eastern cities. The severe winter of 1856–57 caused many deer to starve or be easily killed by settlers in southwestern Wisconsin. Snow was reported to be 6 feet deep in some places with a thick 1/2-inch crust, making movement of deer very difficult. Deer seemed to recover somewhat within a decade and were reported as numerous again in southern Wisconsin in the mid-1860s. Subsistence harvest, together with market hunting, reduced the deer population to the point that deer were considered uncommon throughout southern Wisconsin from 1900 through the 1960s.

Subsistence harvest and market hunting likely reduced the state deer population to its lowest level around 1900 to 1910. Hunting regulations began in 1897, but it wasn't until the 1920s that overhunting was curbed. Conservative harvests in the early 1900s along with regrowth of the northern forest permitted the deer population to increase in the north.

As deer populations grew, the impacts of browsing on forest vegetation became apparent. Starvation of deer was first reported in 1930. From 1934 through 1954, large-scale feeding was done in an effort to prevent starvation. Failure of this feeding program prompted attempts to institute antlerless deer harvests to control and reduce the deer herd. After much public resistance to shooting female deer, the current deer management programs were put in place beginning in the 1960s, setting deer population goals for units within the state and using antlerless deer harvests in an attempt to keep the deer at the established goals. The deer population in the farmlands expanded again in the mid-1960s and especially since the 1980s (Figure 4.14).

Current deer populations in the state are large compared to deer populations prior to Euro-American settlement. Logging and other human activities have kept portions of the forest in northern Wisconsin as primarily young hardwoods, which have provided abundant food for deer. Relatively mild winters during the decades of the 1990s and 2000s reduced winter mortality and allowed the deer herd to increase. Winter feeding of deer by well-intentioned people became popular in the 1990s and may be contributing to increased overwinter survival and increased production of offspring the following spring. Agriculture in southern Wisconsin has provided abundant food resources that support large populations of deer. The current deer management program sets deer population goals for units within the state and uses antlerless deer harvest to keep the deer at the established goal.

Since the mid-1980s, the deer herd has often been above the goals set to maintain ecological sustainability and social acceptance within the state. Land ownership changes have impaired herd control capability. Farmers owned 6 million acres of woodlots in the 1950s, but by the 1990s only 1.5 million acres remained in farmer ownership. Farmers tended to share hunting access whereas the newer owners tend to favor exclusive use. Deer are an important animal for recreation but are causing crop damage, vehicle accidents, and damage to forest regeneration and other plant communities and are a reservoir for Lyme disease (see "Role of White-tailed Deer in the Ecosystem" in Chapter 5, "Current and Emerging Resource Issues").

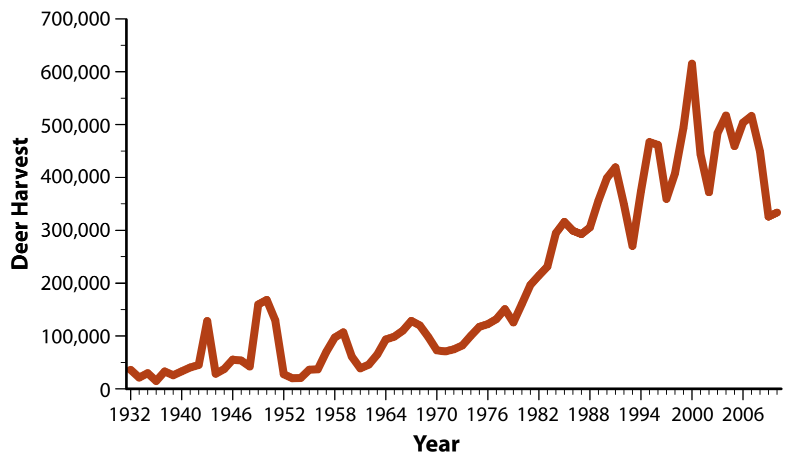


Figure 4.14. *Statewide white-tailed deer harvest from 1932 through 2010.*

Classic straight "browse line" where deer have browsed everything that can be easily reached. Deer herbivory now impacts virtually all forests in the state to varying degrees. Photo by Janeen Laatsch, Wisconsin DNR.

Five different deer management regions are used to manage the deer herd in the state (Figure 4.15):

- The northern forest region has often been over goal since the mid-1980s (Figure 4.16). Only in the time period 2008–2011 have deer populations been reduced somewhat in northern deer management units; however, many deer management units are still above goals. Overbrowsing of more palatable plants is common here, including important trees such as northern white-cedar (*Thuja occidentalis*) and eastern hemlock. Eighty percent of industrial forest ownership has been sold in the past decade. Ownership fragmentation of these lands will complicate resource management.
- The eastern farmland region deer population has often been over goal since the mid-1980s (Figure 4.16), and overbrowsing of more palatable plants and agricultural damage has been common here.
- Western farmland region deer populations have increased dramatically since 1990 (Figure 4.16), and deer are now very abundant. Today, deer cause crop damage, vehicle accidents, damage to forest regeneration, and negative impacts to many forest plants.
- The central forest region has been at or over goal since 1990 (Figure 4.16), and the deer population has increased substantially since 2003, causing crop damage, vehicle accidents, and damage to forest regeneration and other plant communities.
- Southern farmland region deer herds have increased dramatically since 1990 (Figure 4.16). Deer are very abundant in southern Wisconsin and chronically over goal. Deer are an important animal for recreation but are causing crop damage, vehicle accidents, and damage to forest regeneration and other plant communities.

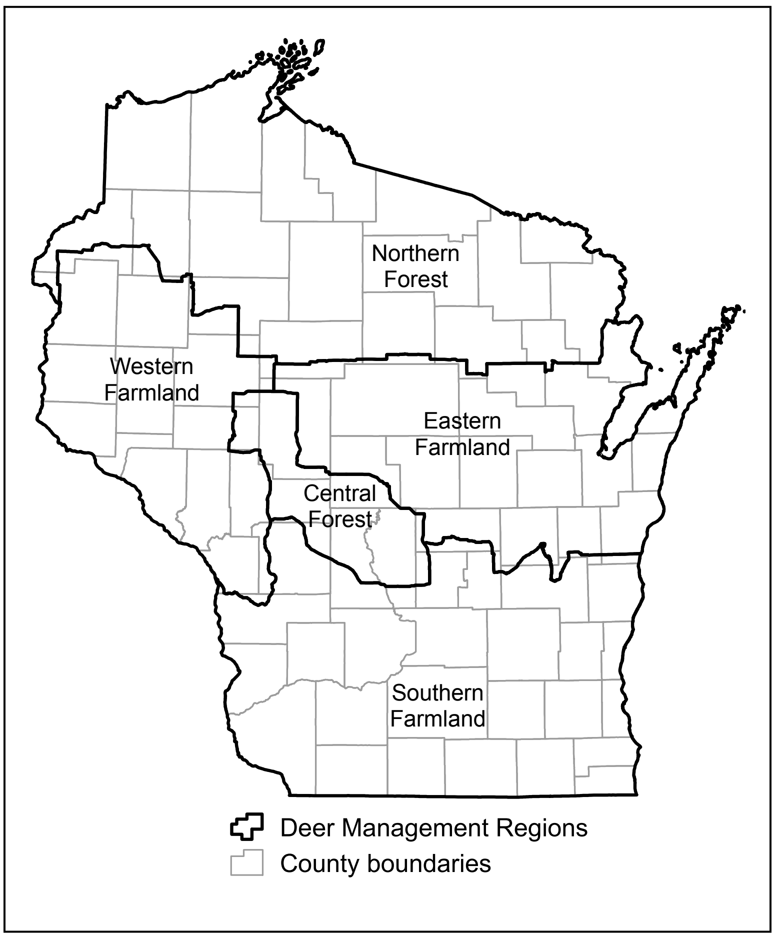


Figure 4.15. *Deer management regions to manage the white-tailed deer herd in Wisconsin.*

White-tailed buck. Photo by Herbert Lange.

White-tailed doe. Photo by Vicki Sokolowski.

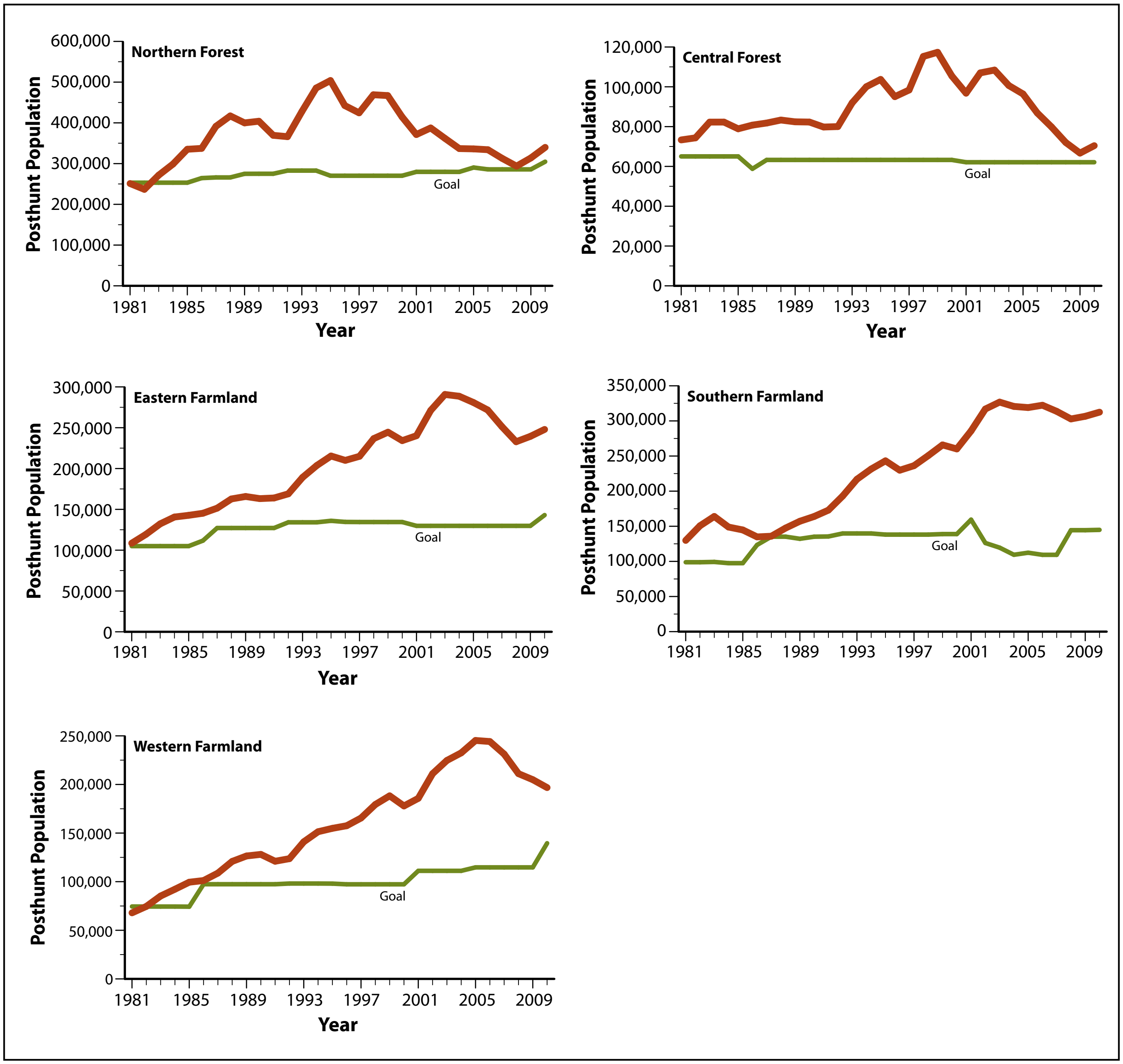


Figure 4.16. *White-tailed deer population size in relation to deer population goals in deer management regions, 1981–2010.*

Overall, herds in the three farmland regions increased four to six fold during the 1962–84 period as farmer tolerance was tested by gradually increasing goals. Herds have since vastly exceeded goals.

Chronic wasting disease (CWD) was discovered in southern Wisconsin and along the Illinois border in 2002. Since then special hunting seasons and regulations have been implemented to reduce the deer herd to contain the disease. CWD disease testing is ongoing to monitor the incidence and potential spread of the disease and to inform hunters of infected deer they may have shot (Figure 4.17).

White-tailed deer have become abundant in parks and metropolitan areas in many parts of the state, causing vehicle-deer collisions and damage to native vegetation and ornamental plantings. Special hunting seasons have been initiated to reduce these deer herds. In addition, costly sharp-shooting and trap-and-remove programs have also been employed to lower deer numbers.

Black Bear

Historically, the black bear was abundant throughout the northern and central parts of Wisconsin. It was also found with less frequency in the southern part of the state. By the late 1880s, bears were gone from the southeastern part of the state and by the mid 1940s from the central part of the state (Schorger 1949). Black bears remained in the north during

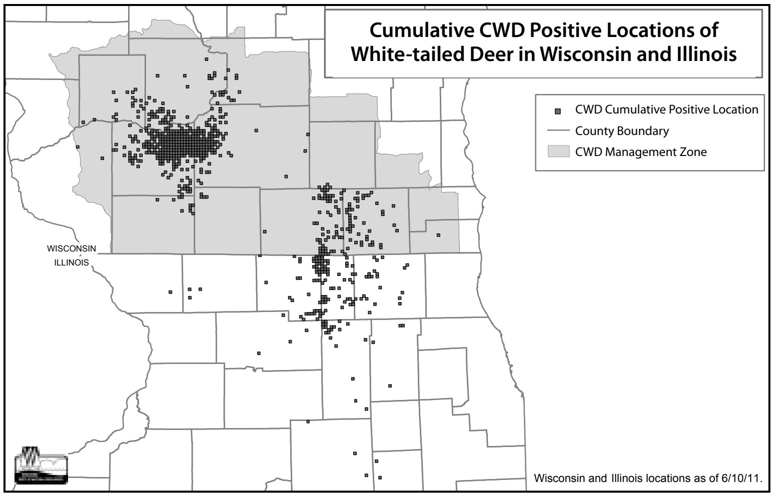


Figure 4.17. *Cumulative locations of CWD-positive deer, 2002–2011, in Wisconsin and Illinois.*

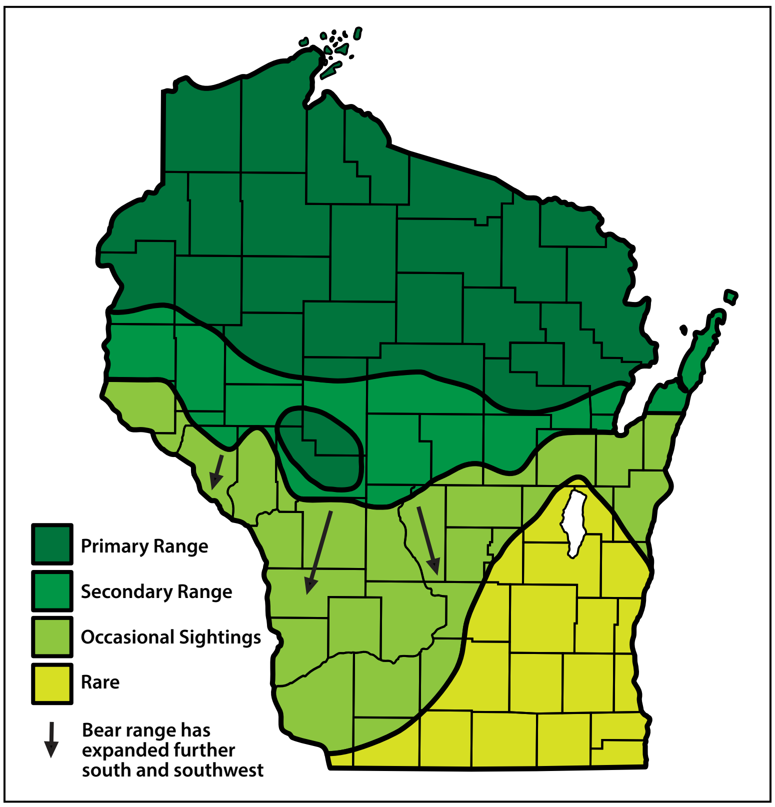


Figure 4.18. *Wisconsin black bear range in 2008. Dark to light: primary range, secondary range, occasional sitings, and rare. Black bear range has expanded further south and southwest.*

this time but in reduced numbers. The status of the black bear evolved from being unprotected to being a managed game species by the 1960s. Black bears have since recolonized central Wisconsin and are wandering into southern Wisconsin with more frequency in recent years (Figure 4.18). Today black bears are carefully managed, and harvests are controlled by a quota system. It is estimated that over 21,000 black bears occurred in the state in 2009 (Rolley and Worland 2009a).

Black bear. Photo by Herbert Lange.

American Beaver

Historically, the American beaver was present in all counties of the state (Schorger 1965), including southern Wisconsin. Milwaukee was a trading and shipping center for beaver pelts from the area south and east of the Wisconsin and Fox rivers. Other trading posts in Green Bay and along Lake Superior and the Wisconsin and Fox rivers shipped large numbers of beaver pelts from other regions of the state to the cities in the eastern United States and Canada. As an example, in 1734–35, 100,000 beaver pelts were shipped from the Upper Mississippi River region. In 1766, 160,000 beaver pelts were shipped from the Lake Pepin area.

Other areas in the state shipped similar numbers of beaver pelts to market. With unregulated trapping and hunting to supply the fur trade through the 1700s, American beaver populations declined dramatically (Schorger 1965). By 1800 very few American beaver were reported taken east of the Mississippi River. By the 1820s most of the fur trade in Wisconsin had ceased, moving to areas west and north of Wisconsin that hadn't been exploited. The American beaver was thought to be near extirpation from Wisconsin by the 1880s. It was sufficiently uncommon during that period "that trapping of one, or presence of its dams, was certain to receive publicity" (Schorger 1965).

In 1912 the American beaver was still present in most of the northern counties in Wisconsin. Seton (1929) reported that only 100 American beavers were left in Wisconsin, but that number is probably too low, since 2,208 American beavers were trapped in the 1933–34 season (Schorger 1965). After laws regulating trapping and offering some protection were enacted, American beaver populations recovered quickly because exploitative logging and fires in prior decades had greatly improved availability of aspen habitat.

American beaver populations have recovered, and beaver are found throughout the state again. Large American beaver populations have negatively affected some coldwater fisheries in parts of the state. Control efforts were made to reduce beaver populations in these areas in the 1990s. Trout stream protection takes precedence over protection of American beaver on high quality trout streams (WDNR 2008a). In addition, American beaver can damage forested wetlands, roads, and, on occasion, building sites.

The American beaver is capable of having great influence—for better or worse—on lakes, streams, springs, and shoreline habitats and can have significant effects on ecosystem composition and structure. In the 1990s, a reduction in the American beaver population in northern Wisconsin was desired, and the population has been reduced by 50% since 1995. A helicopter survey is flown every three years to count active colonies and estimate the size of the American beaver population within each zone (Figure 4.19).

River Otter

Historically, the river otter was abundant in Wisconsin and occurred in every county. River otter populations were supported by the excellent habitat provided by the state's many lakes and streams and an abundance of fish, the river otter's primary food source. Unregulated trapping for the fur trade in the 1700s caused dramatic declines in the state's river otter populations. Based on trapping records from the first half of the 19th century, the river otter was as abundant as, or more abundant than, American beaver across the state (Schorger 1970). The American beaver may have been trapped more frequently during the early fur trade because it was easier to find than the less sedentary river otter. Based on fur harvest records from northern Wisconsin, the river otter population showed a steady decline from the 1830s to 1850 (Schorger 1970).

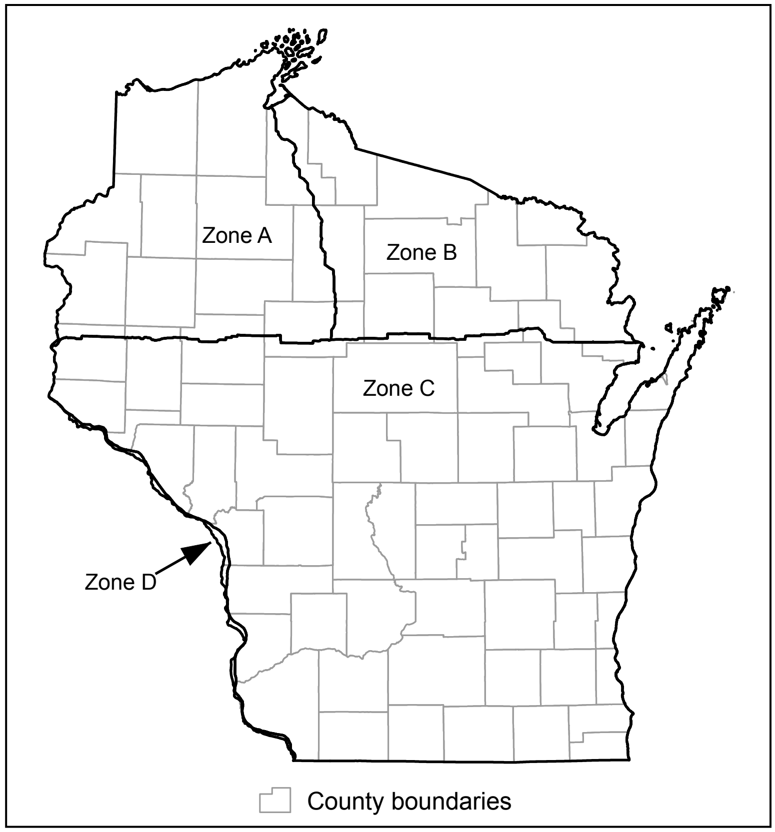


Figure 4.19. *Beaver management zones in Wisconsin.*

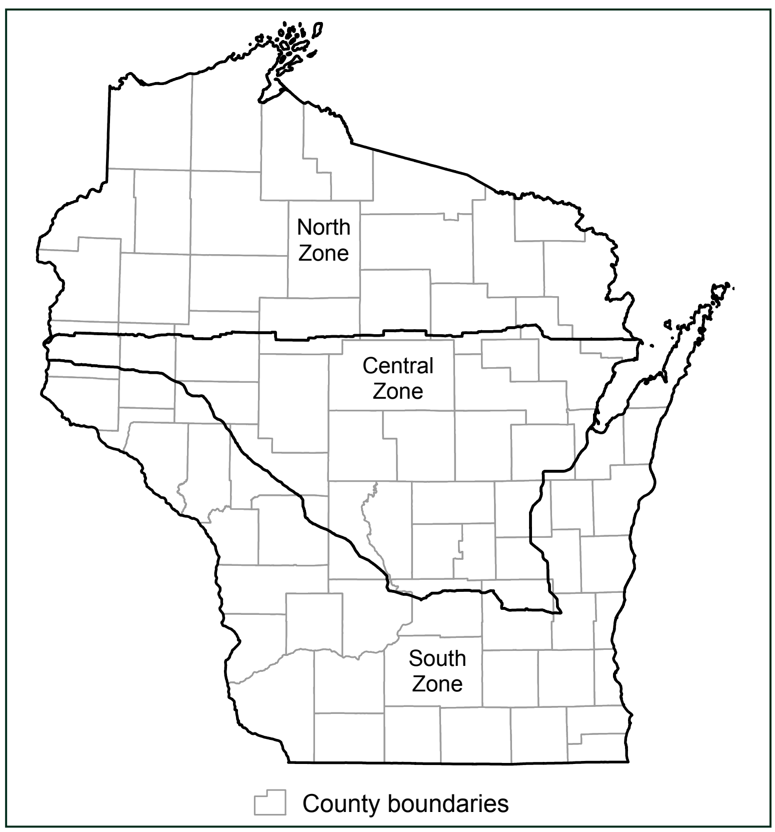


Figure 4.20. *Otter management zones in Wisconsin.*

River otter populations have recovered and are again found throughout the state. In 2010, 10,600 river otters were estimated to be present in the state (Rolley and Worland 2009b). River otter populations are managed by setting population goals for three management zones (Figure 4.20) and adjusting the number of harvest permits needed to maintain the population. River otter harvest goals are set annually for each otter management zone based upon population size in relation to management goals. The number of harvest permits issued is based on the average trapper success rate during the previous three years in those zones. An aerial survey is flown annually, counting the number of river otter tracks crossing a 30-mile transect to estimate the size of the river otter population in the state. In 2009 the river otter population was almost 19% below the goal of 13,000 river otters statewide so harvest permits have been reduced.

Greater Prairie-Chicken

The Greater Prairie-Chicken was found throughout southern Wisconsin before Euro-American settlement (Schorger 1943). The species was considered abundant through the 1850s in southern Wisconsin but later declined.

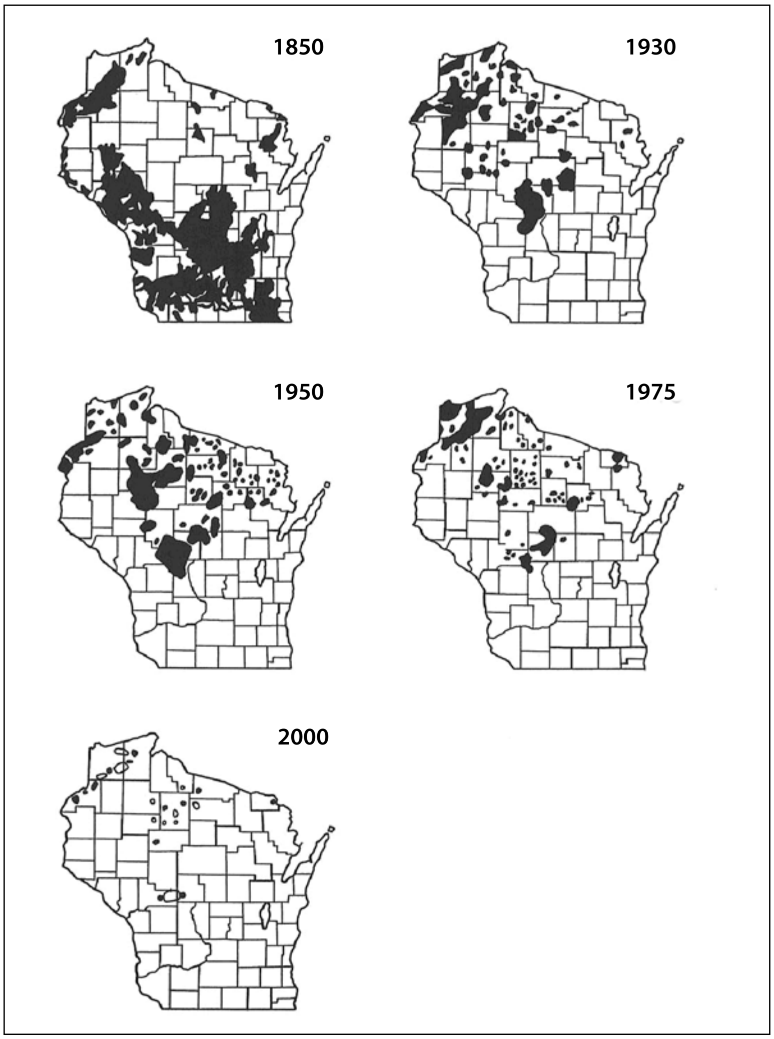


Figure 4.21. *Changes in Sharp-tailed Grouse range since Euro-American settlement. Figure reproduced from Gregg and Niemuth (2000) by permission of the Wisconsin Society for Ornithology.*

Schorger (1943) described reports of Greater Prairie-Chickens brought into Milwaukee in 1842 "by the sleigh load" for the market. Considered "common fare" for the table, great numbers of Greater Prairie-Chickens were shipped by rail to Chicago and eastern cities such as New York and Washington. By 1852 laws were passed to protect Greater Prairie-Chickens from hunting and trapping from January through August. Numbers began plummeting by 1857 after a series of severe winters, wet, cold springs, and years of market hunting and trapping. With the lack of fire, prairies succeeded to brush or were plowed for agriculture, which further contributed to the decline of Greater Prairie-Chickens. At first, agriculture seemed to cause the Greater Prairie-Chicken population to increase, but as agriculture became more intensive, populations declined. By 1900 populations were at very low levels. The range of the Greater Prairie-Chicken shifted north as prairies were plowed for agriculture in the south and forests were logged in central and northern Wisconsin. Forest regeneration in the north constricted the range of the Greater Prairie-Chicken to its present size, primarily limited to central Wisconsin. During 2003–2013, a mean of approximately 400 male Greater Prairie-Chicken males were counted on booming grounds in central Wisconsin. The Greater Prairie-Chicken is currently listed as threatened by the State of Wisconsin.

Sharp-Tailed Grouse

The Sharp-tailed Grouse is believed to have been widely distributed in the state in open and brushy habitats prior to Euro-American settlement, primarily occupying the extensive prairies, oak openings, and barrens (Schorger 1943, Gregg and Niemuth 2000). As prairies were plowed, brushy areas succeeded to forests from lack of fire in the south, and forests were cutover in the north, the range of the Sharp-tailed Grouse shifted (Gregg and Niemuth 2000). The Sharp-tailed Grouse was eliminated from southern Wisconsin, with populations occurring in central and northern Wisconsin. As forests regenerated in the north, the range of the Sharp-tailed Grouse contracted to its present range (Figure 4.21).

As prairie fires ceased, it only took a few years before the land was covered with brush, a habitat more suitable for Sharp-tailed Grouse. Kumlien and Hollister (1903) reported that the Sharp-tailed Grouse was "extremely abundant" and "was the common prairie grouse in southern Wisconsin in 1840." Sharp-tailed Grouse probably expanded into areas as young trees created brushy habitat but then declined because oak openings grew into dense forests or they were replaced by intensive agriculture. Sharp-tailed Grouse became rare throughout southeastern Wisconsin by 1852 and was thought to be nonexistent in southeastern Wisconsin by 1856. Therefore, it was never sent to the markets of the East after the railroads were built, as was the Greater Prairie-Chicken. In southwestern Wisconsin, the Sharp-tailed Grouse persisted longer, with the last documented flock seen near Blue Mounds during the winter of 1939–40 (Schorger 1943).

In central Wisconsin, Sharp-tailed Grouse expanded into areas it had not previously inhabited during and shortly after the Cutover. Later, populations declined as a result of reforestation and/or the expansion of intensive agriculture. In addition, the suppression of wildfires allowed barrens and oak openings to become dense forests, causing further population declines. Most central Wisconsin populations are now associated with large open wetlands, but numbers are very low. For example, only two or three Sharp-tailed Grouse males have been observed on the leks at Dike Seventeen Wildlife Area each year from 2002 to 2007. However, there is still an opportunity to restore barrens habitats, in association with large open wetlands, in central Wisconsin at a scale that could allow Sharp-tailed Grouse populations to recover.

In northwestern Wisconsin, Sharp-tailed Grouse were abundant due to the availability of extensive open, brushy habitats—especially pine barrens. Following the Cutover period of the late 1800s through the early 1900s, Sharp-tailed Grouse briefly became more abundant throughout northern Wisconsin. After Euro-American settlement, the range contracted due to the reduction in wildfire, maturation of the regenerating forests, and the general increase in woody cover. Today, northwestern Wisconsin is the state's last stronghold for the Sharp-tailed Grouse, although small, scattered, isolated populations occur at a few other locations.

In northeastern Wisconsin, the species must have been present historically given the extensive pine barrens habitat present in the past. Schoenebeck (1902) said Sharp-tailed Grouse was a common resident in Oconto County and in the barrens habitat to the north in Marinette County. It was present in this area of the state in 1850 with a remnant population remaining until 2000 (Figure 4.21). Today, the Sharp-tailed Grouse is all but gone from northeastern Wisconsin. With adequate restoration of habitat a viable population might be reestablished. The Sharp-tailed Grouse is currently listed as special concern by the State of Wisconsin.

Spruce Grouse. Photo by Nicholas Anich, Wisconsin DNR.

Spruce Grouse

The Spruce Grouse was historically common in the northern part of the state where conifers were abundant. Although central Wisconsin contained areas with abundant conifers, Spruce Grouse were not documented that far south. After the Cutover, the Spruce Grouse quickly declined. It was difficult to find them in the early 1900s (Schorger 1942a). Today, the Spruce Grouse occurs sporadically across the north where dense stands of conifers are found (Worland et al. 2009). They especially seem to use the edges between upland and lowland conifers. Two population concentration areas occur: one in the Chequamegon-Nicolet National Forest and the other in the Northern Highland-American Legion State Forest (Figure 4.22). The Spruce Grouse is currently listed as threatened by the State of Wisconsin.

Spruce Grouse nest. Photo by Karl Martin, Wisconsin DNR.

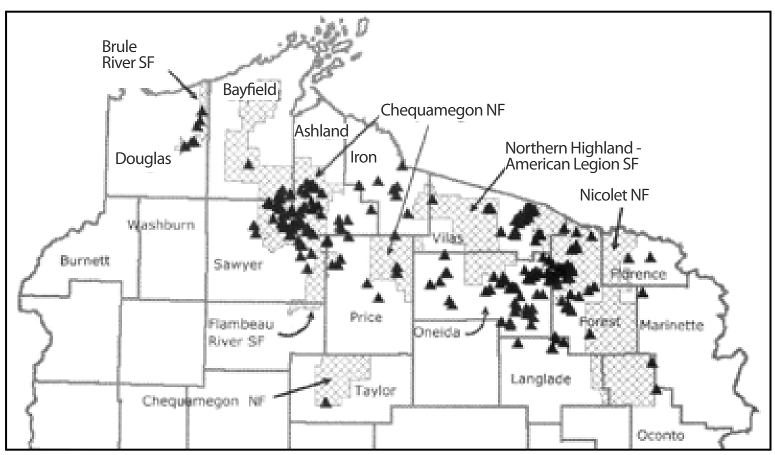


Figure 4.22. *Spruce Grouse observations in Wisconsin from 1980 to 2008 are shown by black triangles. Cross-hatched areas are national and state forests. Figure reproduced from Worland et al. (2009) by permission of the Wisconsin Society for Ornithology.*

Ruffed Grouse

The Ruffed Grouse was found throughout the state prior to Euro-American settlement. It was not common in the northern part of the state where older coniferous and hardwood forests predominated (Schorger 1945). The oak openings in the prairie regions in central, southern, and western Wisconsin provided better habitat (Schorger 1945). Ruffed Grouse were described as abundant there and were often sold in the markets in Milwaukee and Chicago. Settlement initially increased habitat for Ruffed Grouse with the cessation of fire. But by 1870 the decline of Ruffed Grouse began in the southern part of the state. Schorger (1945) stated that the grazing of woodlots was the "chief factor" in this decline. Ruffed Grouse populations increased in the north as logging took place during the latter half of the 19th century. After conifer trees were removed, a younger hardwood habitat became established that was more favorable to Ruffed Grouse. By 1900 the Ruffed Grouse was reported as "almost abundant" in the northern part of the state (Schorger 1945). Today, Ruffed Grouse are common throughout northern and central Wisconsin, although their abundance varies with an 8–10 year population cycle (Figure 4.23). The exact cause of the cycle is unknown, but it is believed to be the result of a number of different factors including food, cover, weather, and predation. They are less abundant in southwestern Wisconsin where the population has been declining dramatically in the last decade due to habitat changes such as isolation of nesting and brood habitats, an increase in invasive species, including exotic shrubs, and increases in predator populations. They are occasionally found elsewhere in southern Wisconsin in pockets of suitable habitat.

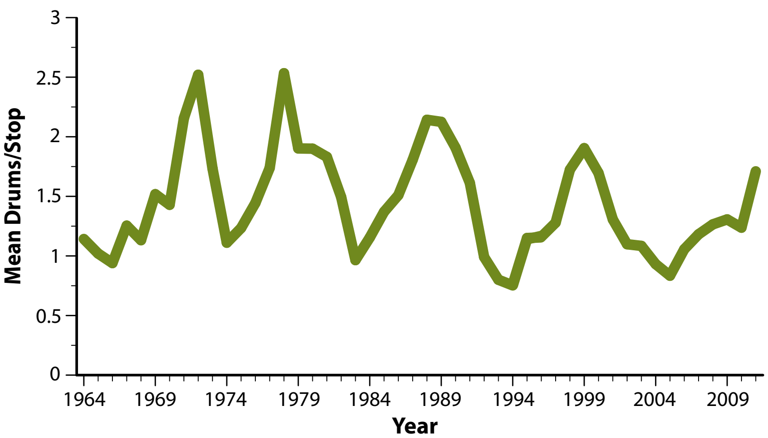


Figure 4.23. *Mean number of drums/stop on ruffed grouse drumming routes, 1964–2010.*

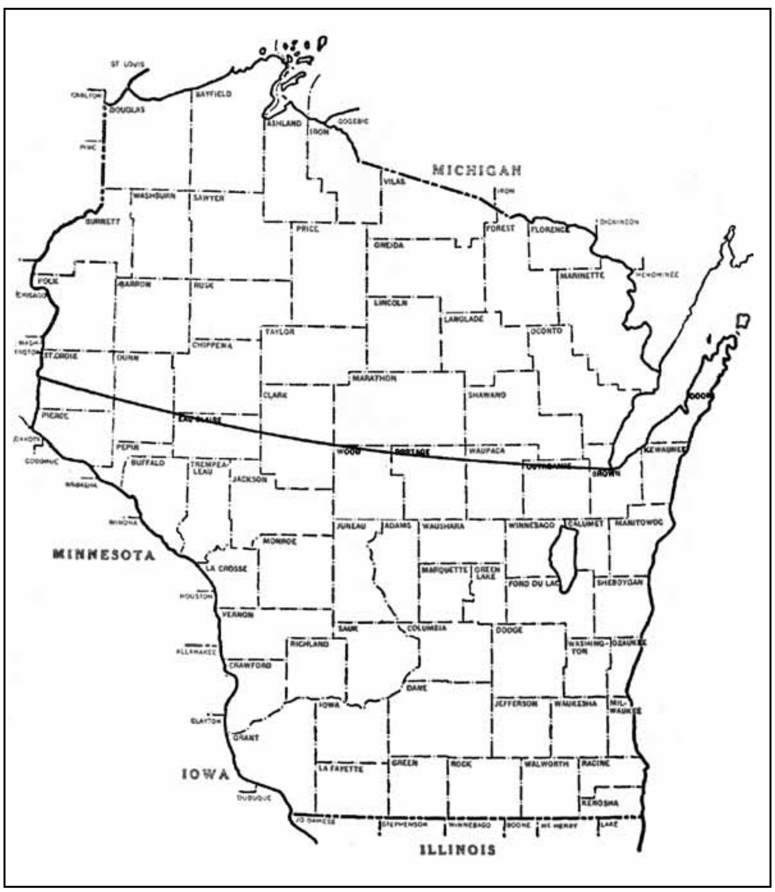


Figure 4.24. *Historical Northern Bobwhite range in southern Wisconsin. Figure reproduced from Schorger (1944) by permission of the Wisconsin Academy of Sciences, Arts and Letters.*

Northern Bobwhite

The Northern Bobwhite was distributed widely throughout the open landscapes in the southern half of the state prior to Euro-American settlement (Schorger 1944, Figure 4.24). However, populations fluctuated widely depending on winter severity. The Northern Bobwhite was very abundant in southern Wisconsin and was especially abundant during a period of mild winters from 1846 to 1857, reaching peak numbers in 1854. Schorger (1944) described an 1854 account that "a good shot can readily bag 50 to 75 in a day" in Madison. Shipments of Northern Bobwhite for market from Beloit to the eastern cities amounted to 12 tons in 1854–55. A shipment of 20,000 Northern Bobwhite from Janesville was received in Philadelphia in 1856. Northern Bobwhite declined quickly thereafter due to unregulated trapping and adverse winter weather. The winters of 1854–55 and 1855–56 were severe, but trapping continued with "tons of quail and other game hanging in the yard of the Capitol House at Madison" (Schorger 1944). The Northern Bobwhite population was much reduced by the fall of 1857 compared to former years. The Northern Bobwhite population recovered somewhat through the 1860s but never to the levels of 1854.

From 1870 to the 1940s, the Northern Bobwhite population remained relatively stationary (Schorger 1944). However, at the close of the 19th century, the Northern Bobwhite population increased temporarily in the Mississippi Valley. Schorger (1944) noted that "they were abundant in 1896 at Prairie du Chien and more numerous than usual at Trempealeau." The increase continued through 1900, and they "were to be found everywhere in the country districts at Prairie du Chien for the first time in many years."

Northern Bobwhite populations decreased dramatically since 1940 because of changes in land use and other causes, such as more intensive farming and maturation of brushy areas to woodlands, which have contributed to their decline. The Northern Bobwhite is still present in the southwestern and central parts of the state in low numbers, with southwestern Wisconsin having the best Northern Bobwhite populations remaining in the state. The Wisconsin DNR made an effort to increase Northern Bobwhite habitat and populations in southwestern Wisconsin during the 1970s and 1980s by planting hedgerows and winter food plots on private lands. These efforts met with little success because habitat was not maintained by private landowners. Moreover, up to 60% of annual variability in Northern Bobwhite population numbers was caused by winter conditions (Petersen 1997).

Canada Goose

The Giant Canada Goose (*Branta canadensis maxima*) was an abundant breeding species in Wisconsin in the 1850s. There were reports of eggs being "gathered by the bushels" during that time period (Wheeler and Cole 1990). Egg collecting, unlimited hunting, and drainage of wetlands reduced the Giant Canada Goose population until it was eliminated from southern Wisconsin in the 1890s and from northern Wisconsin in the 1930s. The Giant Canada Goose was thought to be extinct until a flock was discovered in Minnesota in 1961. Subsequent examination of Canada Goose flocks in Wisconsin at Bay Beach Wildlife Sanctuary and Barkhausen Waterfowl Preserve near Green Bay, Powell Marsh State Wildlife Area (Vilas County), and Crex Meadows Wildlife Area (Burnett County) revealed that they too contained the Giant Canada Goose.

Efforts to reestablish the Canada Goose (*Branta canadensis*) in Wisconsin began in the 1930s with private game breeders (Wheeler and Cole 1990). Most early efforts to stock Canada Geese in Wisconsin used Canada Geese obtained from a private game farm in Minnesota (Thomas Yaeger Game Farm) or from stock from the Yaeger Game Farm via other game farms (e.g., Jack Miner Game Farm). Canada Geese were initially stocked at Barkhausen Waterfowl Preserve in 1932 and then transferred from Barkhausen Preserve to other sites in Wisconsin and Illinois (Wheeler and Cole 1990). The race of the geese stocked in these early attempts is not known but likely contained both *Branta canadensis interior* as well as *Branta canadensis maxima* (Wheeler and Cole 1990).

State and federal efforts to attract migrant Canada Geese to stop at refuges in Wisconsin were begun in the 1930s using captive flocks. Ten captive flocks were established around the state and were composed of trapped or crippled migrants and private game farm stock (Wheeler and Cole 1990). In addition to captive flocks, efforts to stock Canada Geese to other parts of the state began in the 1940s and 1950s. During these early stocking efforts, the race of the Canada Goose was not considered. Most likely the genetic sources of these birds were a mix of migrant Canada Geese (*Branta canadensis interior*) and Giant Canada Geese (Wheeler and Cole 1990). By 1970 Wisconsin had 18 flocks of free-flying resident geese. A second major stocking effort began in the 1980s, using local Canada Geese from these free-flying flocks (Wheeler and Cole 1990).

Resident Canada Geese in Wisconsin today are thought to be a genetic mix of Giant Canada Geese and migrant Canada Geese. Resident Canada Geese have increased dramatically since the 1980s, and stocking Canada Geese was discontinued in the 1990s. Today, resident populations of Canada Geese are found statewide. They present problems in the state's urban areas where they feed on the grassy areas of parks, cemeteries, zoos, golf courses, commercial properties, and private lawns. Sometimes they do damage to agricultural crops.

Bald Eagle

Until the 1800s, Bald Eagles were found throughout Wisconsin. As the state was settled, Bald Eagle populations began to decline. Major causes for their decline were habitat disturbance and destruction and shooting. With the passage of the Migratory Bird Treaty Act in 1918 and the Bald Eagle Protection Act in 1940, it became illegal to shoot the Bald Eagle, but enforcement of the law was weak. By 1950 the Bald Eagle no longer nested in the southern two-thirds of Wisconsin. Bald Eagle populations remained stable in northern Wisconsin until the 1950s, when pesticides such as DDT and other ***organochlorine pesticides*** were commonly used. The use of organochlorine pesticides (particularly DDT/DDE) resulted in thin-shelled eggs that would break before hatching and reduced Bald Eagle productivity. In 1969 DDT was banned in Wisconsin, and in 1972 it was banned nationwide. The same year (1972), the federal government banned the use of other organochlorine pesticides in the United States. In 1973 the Bald Eagle was placed on the federal endangered species list.

With the ban of these pesticides, the Bald Eagle recovered from population lows and reestablished populations in areas from which it had been extirpated (Quamen 2004). Aerial surveys of Bald Eagle nests conducted by the Wisconsin DNR since 1973 documented rising Bald Eagle nest numbers (Figure 4.25). In 2009 there were 1,148 Bald Eagle nest territories occupied by breeding adults. The number of Bald Eagle territories has been almost stable since 2009. Bald Eagles nested in 65 of the state's 72 counties in 2009 (Eckstein et al. 2009). Bald Eagles nesting along the Lake Michigan shore and the lower Fox River of Wisconsin have made a remarkable recovery since 1989. In 1989 only one pair of eagles was known to nest in this entire area (at Kaukauna in Outagamie County). In 2009 there were at least 29 occupied territories along the Lake Michigan shoreline and the lower Fox River. The major inland lakes regions of northwestern and north central Wisconsin (Northern Highland and North Central Forest Ecological Landscapes) hold the state's highest breeding populations of Bald Eagles. Concentrations of breeding Bald Eagles continue to occur on large inland lakes and flowages in Vilas, Oneida, Iron, Sawyer, and Washburn counties (Eckstein et al. 2009). The Bald Eagle was removed from the federal endangered species list in August 2007.

The highest concentration of wintering Bald Eagles in the Midwest is along the Mississippi River. Approximately 4,000 to 7,000 Bald Eagles winter along the Mississippi between Minneapolis and 50 miles south of St. Louis (Iowa DNR 2010). The Mississippi River is an important wintering area for Bald Eagles because of abundant food and open water, particularly at locks and dams and power plants that keep the river from freezing. This provides the Bald Eagle with an area to hunt their primary food source, fish.

Each January an aerial survey of wintering Bald Eagles is flown along a 180-mile route on the lower Wisconsin River from the Petenwell Dam in Adams County to Prairie du Chien in Crawford County. The January 2008 survey recorded 282 Bald Eagles (130 adults and 152 immature Bald Eagles).

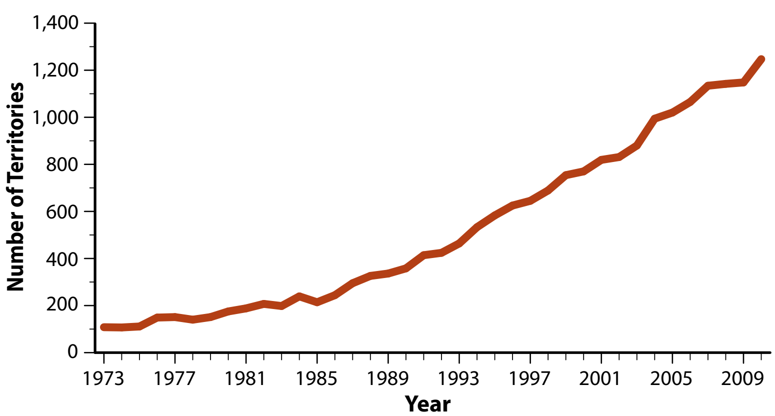


Figure 4.25. *Number of active Bald Eagle territories in Wisconsin, 1973–2009.*

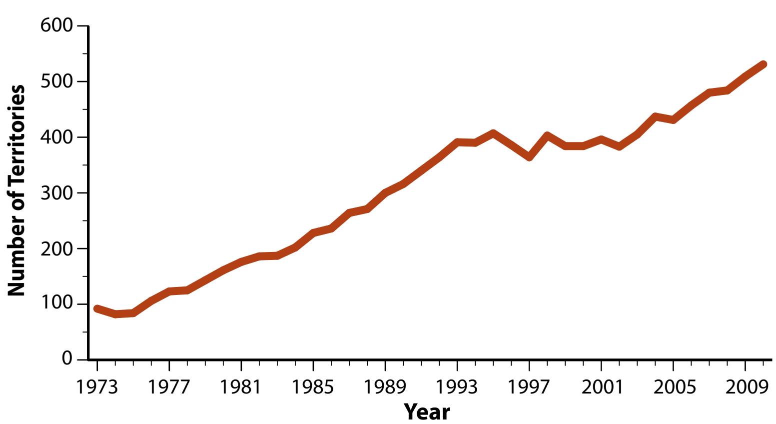


Figure 4.26. *Number of active Osprey territories in Wisconsin, 1973–2009.*

The January 2009 survey recorded 68 Bald Eagles (32 adults and 36 immatures). This survey has been flown since 1992, and the average number of Bald Eagles observed is 130. The record year was 2004 with 614 Bald Eagles observed. The distribution and abundance of wintering Bald Eagles depends on the snow and ice conditions on the Wisconsin River and the surrounding uplands.

Osprey

Before Euro-American settlement, the Osprey nested throughout Wisconsin near major lakes and rivers; however, there are no historical records for nesting along the Mississippi River or on the Apostle Islands (Kumlien and Hollister 1903). Osprey populations declined by the early 1900s due to egg collecting, predation, harvesting of large trees used for nesting, and indiscriminate shooting (Poole et al. 2002). Populations in Wisconsin and throughout the U.S. declined dramatically in the 1950s when the use of organochlorine pesticides was common. In 1972 the Osprey was placed on the Wisconsin endangered species list. The use of organochlorine pesticides (particularly DDT/DDE) resulted in thin-shelled eggs that reduced Osprey productivity.

The combination of banning DDT, prohibiting shooting, protecting nest sites, and providing nesting platforms has helped the Osprey population increase from 82 pairs in 1974 to 509 pairs in 2009 (Eckstein et al. 2009, Figure 4.26), and it has reestablished populations in many areas from

Osprey in flight. This species was removed from Wisconsin's threatened and endangered species list in 2009. Photo by Brian Collins.

which it had been extirpated (Quamen 2004). Aerial surveys of Osprey nests conducted by the Wisconsin DNR since 1973 indicate almost steadily rising Osprey nest numbers (Gieck 1989, Eckstein 1999). As Osprey populations increased, it was moved from the Wisconsin endangered species list to the Wisconsin threatened species list in 1989. In 2006 the statewide population reached 457 pairs and in 2008 increased to 484 pairs. In 2008, 484 pairs of Osprey produced at least 595 young. Nesting pairs continue to spread across Wisconsin, with Osprey pairs now nesting in 49 of the state's 72 counties. Today, breeding pairs are concentrated in the inland lakes regions of north central and northwestern Wisconsin (Northern Highland and North Central Forest Ecological Landscapes) and along the Wisconsin River and its reservoirs in central Wisconsin (Eckstein et al. 2009). Concentrations of breeding Ospreys continue to occur on large inland lakes and flowages in Vilas, Oneida, Iron, Sawyer, Burnett, and Washburn counties. The Osprey was removed from the Wisconsin threatened species list in 2009. However, many countries in Central and South America, where ospreys overwinter, still use DDT and other harmful chemicals. Thus, some ospreys continue to be exposed to these pesticides and their adverse effects.

Common Loon

Although the Common Loon nested as far south as northern Illinois, Iowa, and Indiana historically, its breeding range has retracted north over the last century due to shoreline development and habitat alterations (Zimmer 1979) as well as reductions in lake water quality and clarity. These disturbances continue to reduce available breeding habitat today, particularly on the lakes of northern Wisconsin. McIntyre (1988) described population declines for the Common Loon, especially in the southern part of their range, during the late 19th and early 20th century as habitat was degraded or lost with increasing human use of lakes and development of shorelines. Other causes suspected for population declines are mercury poisoning, ingestion of lead sinkers used for fishing, and oil spills on the wintering grounds. In the early 20th century, the Common Loon was shot for "sport," because it was thought to eat game fish. Development of lakeshores for resorts, homes, cottages, and businesses reduced habitat and increased disturbance levels and likely forced the Common Loon to nest in less optimal habitat where they may have reduced productivity (McIntyre 1988).

Although no clear continent-wide trends in Common Loon population size have been reported for the last two decades, there appear to have been substantial population increases in southern parts of the breeding range during the mid to late 1900s, including Wisconsin. Summarizing reports based on North American Breeding Bird Surveys from 1969 and 1989, McIntyre and Barr described a 124% increase in the Common Loon population in Wisconsin (Dunn 1993). These breeding bird survey results showing that large population increases in Wisconsin and elsewhere may represent recovery from the declines described for the early 20th century (McIntyre 1988). The Wisconsin LoonWatch program reports stable Common Loon population numbers based on 1985–2000 survey data (Gostomski and Rasmussen 2001). As lakeshores are developed for housing, there is concern that Common Loon nesting habitat will continue to decline.

Common Loons may be vulnerable to oil spills, chemical contaminants, energy developments such as wind farms, and diseases on their wintering grounds and migration routes.

Sandhill Crane

Until 1850, the Sandhill Crane was a common breeding bird in the state (Schorger 1942a). It occurred in the largest numbers in areas of the state with abundant prairies and marshes. It declined dramatically due to habitat loss and change, nest predation, disturbance by man, and hunting. By the early 1950s the breeding population of the Sandhill Crane in Wisconsin was estimated to be only 25 breeding pairs (Schorger 1942a). Since then the Sandhill Crane has made a remarkable comeback and is now again a common breeding bird in parts of the state.

An adult loon swims with its chick on its back. Photo by Herbert Lange.

Sandhill Crane. Photo by Steve Emmons, U.S. Fish and Wildlife Service.

Timber Rattlesnake

The timber rattlesnake was abundant prior to Euro-American settlement but was restricted to southwestern Wisconsin (Figure 4.27) (primarily the Western Coulees and Ridges Ecological Landscape). It has never been found east of Madison. It occurred in the uplands, especially where there were rock outcroppings and rock crevices where it could hibernate. At the time of Euro-American settlement they were very abundant. The Cooke family killed 150 rattlesnakes during their first year near Gilmanton (Trempealeau County) in 1856 (Cooke 1940). Messeling (1953) stated that he killed a thousand rattlesnakes for their bounty each year. As late as the mid-1960s, Crawford County paid a bounty for 10,000–11,000 rattlesnakes a year. Early settlers used pigs to kill and eat rattlesnakes as a means of controlling them on their farms (Schorger 1967). Although the timber rattlesnake still occurs here, populations have been greatly reduced by land use changes and continued persecution. The species is now listed as Wisconsin Special Concern. It is protected by special harvest regulations, and there are no longer bounties paid for killing rattlesnakes.

Eastern Massasauga Rattlesnake

The eastern massasauga rattlesnake was found throughout southern and central Wisconsin at the time of Euro-American settlement (Figure 4.27).

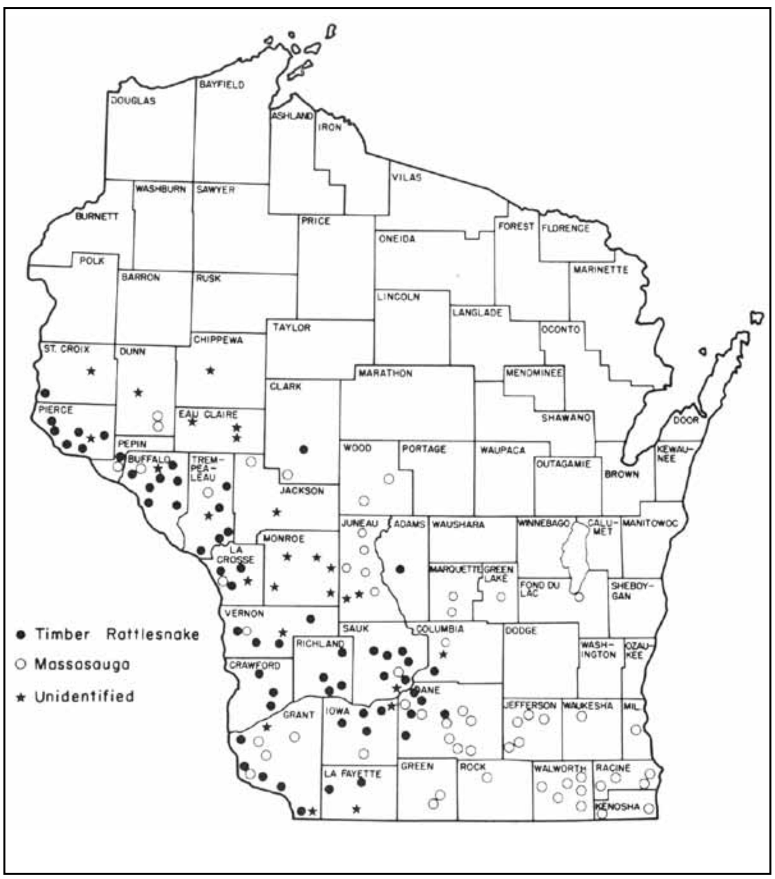


Figure 4.27. *Historical timber and massasauga rattlesnake range in Wisconsin. Reproduced from Schorger (1967) by permission of the Wisconsin Academy of Sciences, Arts and Letters.*

It occupied marshy areas, lowland prairies, and areas along streams. It was considered very abundant in some areas at the time of Euro-American settlement. The eastern massasauga rattlesnake has also been dramatically reduced by land use changes and relentless persecution. It is still occasionally found along the Chippewa and Black rivers and in parts of central Wisconsin. The eastern massasauga rattlesnake is more sensitive to habitat changes than the timber rattlesnake and is now listed as Wisconsin Endangered and is a formal ***candidate species*** for federal listing.

Introduced Species

Ring-Necked Pheasant

Introduction of a variety of races of Ring-necked Pheasants began in the 1890s (Schorger 1947). In 1895 the Wisconsin legislature passed a law making it illegal to "take, catch, or kill any Mongolian, Chinese, or English Pheasants, or any other variety of pheasants for a period of five years" to provide protection while attempting to establish populations. Many early releases were unsuccessful, but the nonnative Ring-necked Pheasant became established in many parts of the southern two-thirds of Wisconsin where it is present in huntable numbers today.

Gray Partridge

The Gray Partridge was introduced from Eurasia into southern Wisconsin and was abundant for a period of years. In recent decades it has declined significantly. Harvest has declined by 95% since 1983 (Dhuey 2011). More intensive farming (e.g., early hay mowing, clean corn and grain harvesting methods, loss of winter cover) may be the reason for this decline. East central Wisconsin is considered the primary range in the state for this species, but it is not common anywhere (Cutright et al. 2006).

Capercaillie and Black Grouse

In 1949 Capercaillie (*Tetrao urogallus*) and Black Grouse (*Tetrao tetrix*) were introduced to Outer Island on Lake Superior by the Wisconsin Conservation Department (Gjestson 2013). Sixty birds were obtained from Europe for this attempt. Interestingly, 201 were also released on Grand Island, a Lake Superior site in Michigan. All release attempts failed.

Appendix 4.A. *Scientific names of species mentioned in the text.*

Common name	Scientific name
Acadian hairstreak	*Satyrium acadica*
Alewife	*Alosa pseudoharengus*
American basswood	*Tilia americana*
American beaver	*Castor canadensis*
American beech	*Fagus grandifolia*
American bison	*Bos bison*
American marten	*Martes americana*
Aspen	*Populus* spp.
Autumn olive	*Elaeagnus umbellata*
Badger	*Taxidea taxus*
Bald Eagle[a]	*Haliaeetus leucocephalus*
Baltimore checkerspot	*Euphydryas phaeton*
Benthic amphipod	*Diporeia hoyi*
Big brown bat	*Eptesicus fuscus*
Black bear	*Ursus americanus*
Black carp	*Mylopharyngodon piceus*
Black cherry	*Prunus serotina*
Black dash skipper	*Euphyes conspicua*
Black Grouse	*Tetrao tetrix*
Black locust	*Robinia pseudoacacia*
Black spruce	*Picea mariana*
Bloater	*Coregonus hoyi*
Blue Jay	*Cyanocitta cristata*
Bobcat	*Lynx rufus*
Brambles	*Rubus* spp.
Broad-winged skipper	*Poanes viator*
Brown trout	*Salmo trutta*
Brown-headed Cowbird	*Molothrus ater*
Canada Goose	*Branta canadensis*
Capercaillie	*Tetrao urogallus*
Caribou	*Rangifer tarandus*
Carolina Wren	*Thryothorus ludovicianus*
Chinook salmon	*Oncorhynchus tschawytscha*
Ciscoes	*Coregonus* spp.
Common carp	*Cyprinus carpio*
Common Loon	*Gavia immer*
Common prickly-ash	*Zanthoxylum americanum*
Common reed	*Phragmites australis*
Common ringlet	*Coenonympha tullia*
Cooper's Hawk	*Accipiter cooperii*
Cope's gray tree frog	*Hyla chrysoscelis*
Cougar	*Puma concolor*
Coyote	*Canis latrans*
Curly pondweed	*Potamogeton crispus*
Daphnia	*Daphnia* spp.
Dion skipper	*Euphyes dion*
Double-crested Cormorant	*Phalacrocorax auritus*
Dune (Pitcher's) thistle	*Cirsium pitcheri*
Eastern Bluebird	*Sialia sialis*
Eastern cottontail rabbit	*Sylvilagus floridanus*
Eastern hemlock	*Tsuga canadensis*
Eastern massasauga rattlesnake	*Sistrurus catenatus catenatus*
Eastern pipistrelle	*Perimyotis subflavus*
Eastern white pine	*Pinus strobus*
Elk	*Cervus elaphus*

Continued on next page

Appendix 4.A, *continued.*

Common name	Scientific name
Elm	*Ulmus* spp.
Eurasian buckthorns	*Rhamnus cathartica* and *R. frangula*
Eurasian honeysuckles	*Lonicera morrowii* and *L. tatarica*
Eurasian water-milfoil	*Myriophyllum spicatum*
European Starling	*Sturnus vulgaris*
Eyed brown	*Satyrodes eurydice eurydice*
Fisher	*Martes pennanti*
Garlic mustard	*Alliaria petiolata*
Giant Canada Goose	*Branta canadensis maxima*
Gophersnake (bullsnake)	*Pituophis catenifer*
Grasshopper Sparrow	*Ammodramus savannarum*
Gray fox	*Urocyon cinereoargenteus*
Gray Partridge	*Perdix perdix*
Gray wolf	*Canis lupus*
Greater Prairie-chicken	*Tympanuchus cupido*
Greenish blue butterfly	*Plebejus saepiolus*
House Finch	*Carpodacus mexicanus*
House mouse	*Mus musculus*
House Sparrow	*Passer domesticus*
Interior Canada Goose	*Branta canadensis interior*
Ironwood	*Ostrya virginiana*
Jack pine	*Pinus banksiana*
Japanese barberry	*Berberis thunbergii*
Kirtland's Warbler	*Setophaga kirtlandii,* listed as *Dendroica kirtlandii* on the Wisconsin Natural Heritage Working List
Lake Huron tansy	*Tanacetum huronense*
Lake trout	*Salvelinus namaycush*
Large-flowered bellwort	*Uvularia grandiflora*
Little brown bat	*Myotis lucifugus*
Long-billed Curlew	*Numenius americanus*
Lyme grass	*Leymus arenarius*
Lynx	*Lynx canadensis*
Mead's milkweed	*Asclepias meadii*
Moose	*Alces alces*
Mulberry wing skipper	*Poanes massasoit*
Multiflora rose	*Rosa multiflora*
Mustard white	*Pieris napi*
Mute Swan	*Cygnus olor*
North American racer	*Coluber constrictor*
Northern Bobwhite	*Colinus virginianus*
Northern cricket frog	*Acris crepitans*
Northern leopard frog	*Lithobates pipiens*
Northern long-eared bat	*Myotis septentrionalis*
Northern white-cedar	*Thuja occidentalis*
Norway rat	*Rattus norvegicus*
Oak	*Quercus* spp.
Ornate box turtle	*Terrapene ornata*
Osprey	*Pandion haliaetus*
Passenger Pigeon	*Ectopistes migratorius*
Peregrine Falcon	*Falco peregrinus*
Pickerel frog	*Lithobates palustris*
Poison ivy	*Toxicodendron radicans*
Purple loosestrife	*Lythrum salicaria*
Quagga mussel	*Dreissena bugensis*
Queen snake	*Regina septemvittata*

Continued on next page

Appendix 4.A, *continued.*

Common name	Scientific name
Raccoon	*Procyon lotor*
Rainbow smelt	*Osmerus mordax*
Rainbow trout	*Oncorhynchus mykiss*
Red fox	*Vulpes vulpes*
Red maple	*Acer rubrum*
Red pine	*Pinus resinosa*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Reed canary grass	*Phalaris arundinacea*
Ring-necked Pheasant	*Phasianus colchicus*
River otter	*Lutra canadensis*
Round goby	*Neogobius melanostomus*
Ruffed Grouse	*Bonasa umbellus*
Rusty crayfish	*Orconectes rusticus*
Salmon	*Oncorhynchus* spp.
Sandhill Crane	*Grus canadensis*
Sea lamprey	*Petromyzon marinus*
Sharp-tailed Grouse	*Tympanuchus phasianellus*
Six-lined racerunner	*Aspidoscelis sexlineata*
Snapping turtle	*Chelydra serpentina*
Snowshoe hare	*Lepus americanus*
Spotted knapweed	*Centaurea biebersteinii*
Spring blue-eyed-Mary	*Collinsia verna*
Spring peeper	*Pseudacris crucifer*
Spruce Grouse	*Falcipennis canadensis*
Sugar maple	*Acer saccharum*
Tamarack	*Larix laricina*
Timber rattlesnake	*Crotalus horridus*
Toothworts	*Dentaria* spp.
Trumpeter Swan	*Cygnus buccinator*
Tufted Titmouse	*Baeolophus bicolor*
Two spotted skipper	*Euphyes bimacula*
Virginia opossum	*Didelphis virginiana*
Voles	*Microtus* spp.
Walleye	*Sander vitreus*
West Virginia white	*Pieris virginiensis*
Western Meadowlark	*Sturnella neglecta*
Western slender glass lizard	*Ophisaurus attenuatus*
White birch	*Betula papyrifera*
White nose syndrome fungus	*Geomyces destructans*
White-tailed deer	*Odocoileus virginianus*
Whooping Crane	*Grus americana*
Wild Turkey	*Meleagris gallopavo*
Yellow birch	*Betula alleghaniensis*
Yellow perch	*Perca flavescens*
Zebra mussel	*Dreisennia polymorpha*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologists Union.

Literature Cited

Allen, R.P. 1952. *The Whooping Crane*. National Audubon Society, Resource Report 3, New York.

Arbogast, A.F., and S.C. Packman. 2004. Middle-Holocene mobilization of aeolian sand in western upper Michigan and the potential relationship with climate and fire. *The Holocene* 14:464–471.

Asplund, T., and C. Cook. 1997. Effects of motor boats on submerged aquatic macrophytes. *Lake Reservoir Management* 13:1–12.

Baker, R.G., E.A. Bettis III, R.F. Denniston, L.A. Gonzalez, L.E. Strickland, and J.R. Krieg. 2002. Holocene paleoenvironments in southeastern Minnesota—chasing the prairie-forest ecotone. *Palaeogeography, Palaeoclimatology, Palaeoecology* 177:103–122.

Baker, R.G., L.J. Maher, C.A. Chumbley, and K.L. Van Zant. 1992. Patterns of Holocene environmental change in the midwestern United States. *Quaternary Research* 37:379–389.

Bartlein, P.J., K.H. Anderson, P.M. Anderson, M.E. Edwards, C.J. Mock, R.S. Thompson, R.S. Webb, T. Webb III, and C. Whitlock. 1998. Paleoclimate simulations for North America over the past 21,000 years: features of the simulated climate and comparisons with paleoenvironmental data. *Quaternary Science Reviews* 17:549–586.

Bergeson, T., and J. Kitchell. 2008. Frog and toad survey. Wisconsin wildlife reports. Web page. Wisconsin Department of Natural Resources, Madison. Available online at http://dnr.wi.gov/topic/wildlifehabitat/reports.html. Accessed March 2011.

Bersing, O.S. 1966. *A century of Wisconsin deer*. Second edition. Wisconsin Conservation Department, Game Management Division, Publication 353, Madison. 272 pp.

Booth, R.K., S.T. Jackson, S.L. Forman, J.E. Kutzbach, E.A. Bettis III, J. Kreigs, and D. K. Wright. 2005. A severe centennial-scale drought in midcontinental North America 4200 years ago and apparent global linkages. *The Holocene* 15:321–328.

Booth, R.K., M. Notaro, S.T. Jackson, and J.E. Kutzbach. 2006. Widespread drought episodes in the western Great Lakes region during the past 2000 years: geographic extent and potential mechanisms. *Earth and Planetary Science Letters* 242:415–427.

Brockman, K.M., and R.A. Dow Jr., editors. 1982. *Wildlife in early Wisconsin: a collection of works by A.W. Schorger*. Student Chapter of The Wildlife Society, Stevens Point, Wisconsin.

Brown, C.L., and W.E. Vander Zouwen. 1993. *Wisconsin turkey hunter's guide.* Wisconsin Department of Natural Resources, PUB-WM-214-2004, Madison. 40 pp.

Brubaker, L.B. 1975. Postglacial forest patterns associated with till and outwash in north central upper Michigan. *Quaternary Research* 5:499–527.

Brugam, R.B., M. Giorgi, C. Sesvold, S.M. Johnson, and R. Almos. 1997. Holocene vegetation history in the Sylvania Wilderness area of the western Upper Peninsula of Michigan. *American Midland Naturalist*, 137:62–71.

Brugam, R.B., B. Owen, and L. Kolesa. 2004. Continental-scale climate forcing factors and environmental change at Glimmerglass Lake in the Upper Peninsula of Michigan. *The Holocene* 14:807–817.

Burney, D.A., and T.F. Flannery. 2005. Fifty millennia of catastrophic extinctions after human contact. *Trends in Ecology and Evolution* 20:395–401.

Calcote, R. 2003. Mid-Holocene climate and the hemlock decline: the range limit of Tsuga canadensis in the western Great Lakes region, USA. *The Holocene* 13:215–224.

Carr, C.F., editor. 1890. A list of the birds known to nest within the boundaries of Wisconsin, with a few notes thereon. *Wisconsin Naturalist* 1:2–6.

Casper, G.S. 2008. Changes in amphibian and reptile communities. Pages 287–300 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Christensen, D.L., B.R. Herwig, D.E. Schindler, and S.R. Carpenter. 1996. Impacts of shoreline residential development on coarse woody debris. *Ecological Applications* 6(4):1143–1149.

Clark, J.S., E.C. Grimm, J. Lynch, and P.G. Mueller. 2001. Effects of Holocene climate change on the C4 grassland/woodland boundary in the northern plains, USA. *Ecology* 82:620–636.

Cooke, W.W. 1940. A frontiersman in northwestern Wisconsin. *The Wisconsin Magazine of History* 23(4):405–426.

Curtis, J. 1959. *The vegetation of Wisconsin: an ordination of plant communities*. University of Wisconsin Press, Madison. 657 pp.

Cutright, N.J., B.R. Harriman, and R.W. Howe. 2006. *Atlas of the breeding birds of Wisconsin*. Wisconsin Society for Ornithology, Waukesha. 602 pp.

Dahl, T. 1990. *Wetlands: losses in the United States 1780s to 1980s.* U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, D.C. 19 pp.

Dahl, T.E. 2006. *Status and trends of wetlands in the conterminous United States 1998 to 2004.* U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, D.C. 112 pp. Available online at http://www.fws.gov/wetlands/Status-And-Trends-2009/index.html.

Daniels, E. 1854. *First annual report on the geological survey of the State of Wisconsin. Madison, Wisconsin.* Report submitted by the State Geologist to the Governor of Wisconsin, Madison. Available online at http://digital.library.wisc.edu/1711.dl/EcoNatRes.GNR1854.

Davis, B.A.S., S. Brewer, A.C. Stevenson, and J. Guiot. 2003. The temperature of Europe during the Holocene reconstructed from pollen data. *Quaternary Science Reviews* 22:1701–1716.

Davis, M.B., R.R. Calcote, S. Sugita, and H. Takahara. 1998. Patchy invasion and the origin of a hemlock-hardwood forest mosaic. *Ecology* 79:2641–2659.

Davis, M.B., S. Sugita, R.R. Calcote, J.B. Ferrari, and L.E. Frelich. 1993. Historical development of alternate communities in a hemlock-hardwood forest in northern Michigan, U.S.A. Pages 19–39 *in* P.J. Edwards, R.M. May, and N.R. Webb, editors. *Large-scale ecology and conservation biology: the 35th symposium of the British Ecological Society with the Society for Conservation Biology*. Blackwell Scientific Publications, Boston, Massachusetts.

Davis, M.B., K.D. Woods, S.L. Webb, and R.P. Futyma. 1986. Dispersal versus climate: expansion of Fagus and Tsuga into the Upper Great Lakes region. *Vegetatio* 67:93–103.

Dhuey, B. 2011. Ruffed Grouse drumming survey 2011. Wisconsin DNR wildlife reports web page. Available online at http://dnr.wi.gov/topic/wildlifehabitat/reports.html. Accessed January 3, 2013.

Dhuey, B. 2011. Small game harvest 2010–2011. Wisconsin DNR wildlife reports web page. Available online at http://dnr.wi.gov/topic/wildlifehabitat/reports.html. Accessed January 3, 2013.

Diamond, J. 1997. *Guns, germs, and steel: the fates of human societies*. W.W. Norton, New York. 480 pp.

Dott, R., Jr., and J. Attig. 2004. *Roadside geology of Wisconsin*. Mountain Press Publishing Company, Missoula, Montana. 346 pp.

Dunn, T.B. 1993. Status of the Common Loon in Wisconsin. Pages 132–159 *in* L. Morse, S. Stockwell, and M. Porkras, editors. *The loon and its ecosystem: status, management, and environmental concerns. 1992 American Loon Conference Proceedings*. U.S. Dept. of the Interior, Fish and Wildlife Service, Concord, New Hampshire.

Eckstein, R.G. 1999. The Osprey in Wisconsin. *The Passenger Pigeon* 61:271–275.

Eckstein, R., G. Dahl, S. Easterly, B. Ishmael, J. Nelson, P. Manthey, M. Meyer, L. Tesky, D. Goltz, and B. Glenzinski. 2009. *Wisconsin Bald Eagle and Osprey surveys 2009.* Wisconsin DNR wildlife reports web page. Available online at http://dnr.wi.gov/topic/wildlifehabitat/reports.html. Accessed April 2010.

Elias, J.E., and M.W. Meyer. 2003. Comparisons of undeveloped and developed shorelands, northern Wisconsin, and recommendations for restoration. *Wetlands* 23(4):800–816.

Ewing, H.A. 2002. The influence of substrate on vegetation history and ecosystem development. *Ecology* 83:2766–2781.

Ferge, L. 2008. Changes in butterfly and moth fauna. Pages 338–349 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife.* University of Chicago Press, Chicago. 416 pp.

Fiedel, S.J., and G. Haynes. 2004. A premature burial: comments on Grayson and Meltzer's "Requiem for overkill." *Journal of Archaeological Science* 31:121–131.

Frelich, L.E., and P.B. Reich. 2009. Wilderness conservation in an era of global warming and invasive species: a case study from Minnesota's Boundary Waters Canoe Area Wilderness. *Natural Areas Journal* 29:385–393.

Gieck, C.M. 1989. Wisconsin Bald Eagle recovery plan. *The Passenger Pigeon* 51:335–341.

Gjestson, D.L. 2013. *The gamekeepers: Wisconsin wildlife conservation from WCD to CWD*. Wisconsin Department of Natural Resources, Madison.

Gostomski, T.J., and P.W. Rasmussen. 2001. Results of the 2000 Common Loon survey in Wisconsin. *The Passenger Pigeon* 63:15–25.

Graumlich, L.J., and M.B. Davis. 1993. Holocene variation in spatial scales of vegetation pattern in the upper Great Lakes. *Ecology* 74:826–839.

Grayson, D.K., and D.J. Meltzer. 2003. A requiem for North American overkill. *Journal of Archaeological Science* 30(2003):585–593.

Gregg, L.E., and N. Niemuth. 2000. The history, status, and future of Sharp-Tailed Grouse in Wisconsin. *The Passenger Pigeon* 62(2):158–174.

Hendrix, P.F., and P.J. Bohlen. 2002. Exotic earthworm invasions in North America: ecological and policy implications. *BioScience* 52(9):801–811.

Hotchkiss, S.C., R. Calcote, and E.A. Lynch. 2007. Response of vegetation and fire to Little Ice Age climate change: regional continuity and landscape heterogeneity. *Landscape Ecology* 22:25–41.

Hoy, P.R. 1885. Man's influence on the avifauna of southeastern Wisconsin. *Proceedings of the Natural History Society of Wisconsin* March 1885:4–9.

Hunt, R., K. Bradbury, and J. Krohelski. 2001. The effects of large scale pumping and diversion of water resources in Dane County. U.S. Geological Survey, Fact Sheet FS-127-01, Middleton, Wisconsin.

Hupy, C.M., and C.H. Yansa. 2009. Late Holocene vegetation history of the forest tension zone in central Lower Michigan, USA. *Physical Geography* 30:205–235.

Iowa Department of Natural Resources (DNR). 2010. Bald Eagles in Iowa. Brochure. Iowa Department of Natural Resources, Boone, Iowa. Available online at http://www.iowadnr.gov/portals/idnr/uploads/education/Species/birds/pub_baldeagle.pdf. Accessed July 2010.

Jackson, H.H.T. 1961. *Mammals of Wisconsin*. University of Wisconsin Press, Madison. 504 pp.

Jackson, S.T., and R.K. Booth. 2002. The role of Late Holocene climate variability in the expansion of yellow birch in the western Great Lakes region. *Diversity and Distributions* 8:275–284.

Judziewicz, E., and J. Nekola. 2000. Recent Wisconsin records for some interesting vascular plants in the western Great Lakes region. *The Michigan Botanist* 36:91–118.

Kitchell, J.F., and G.G. Sass. 2008. Great Lakes ecosystems: invasions, food web dynamics, and the challenge of ecological restoration. Pages 157–170 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Kohn, B.E., and R.G. Eckstein. 1985. *Status of marten in Wisconsin.* Wisconsin Department of Natural Resources, Research Report 143, Madison.

Kohn, B.E., N.F. Payne, J.A. Ashbrenner, and W.E. Creed. 1993. *The fisher in Wisconsin.* Wisconsin Department of Natural Resources, Technical Bulletin 183, Madison. 24 pp.

Kumlien, L., and N. Hollister. 1903. The birds of Wisconsin. *Bulletin of the Wisconsin Natural History Society* 2:1–143.

Kucharik, C.J. 2008. Soil response to re-establishment of prairie communities in southern Wisconsin. Pages 106–107 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Leach, M. 1996. *Gradients in groundlayer composition, structure, and diversity in remnant and experimentally restored oak savannas.* Ph.D. dissertation. University of Wisconsin–Madison, Madison.

Leach, M. 2008. Savanna and prairie: requiem for the past, hope for the future. Pages 103–114 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Leach, M., and T. Givnish. 1999. Gradients in the composition, structure, and diversity of remnant oak savannas in southern Wisconsin. *Ecological Monographs* 69(3):353–374.

Leopold, A. 1931. *Report on a game survey of the North Central states.* Sporting Arms and Ammunition Manufacturers' Institute, Committee on Restoration and Protection of Game, Madison, Wisconsin. 299 pp.

Lorimer, C. 1984. Development of the red maple understory in northeastern oak forests. *Forest Science* 30:3–22.

Maher, L. 1997. PLOT2.EXE, PLOTOVER.EXE, and PLOTLIM.EXE: specialty programs for special problems. INQUA Commission for the Study of the Holocene, Sub-Commission on Data-Handling Methods. *Newsletter* 15:6–9. Available online at http://www.chrono.qub.ac.uk/inqua/news15/n15-ljm1.htm. Accessed February 19, 2010.

Mann, C.C. 2005. *1491: new revelation of the Americas before Columbus*. Alfred A. Knopf, New York. 541 pp.

Mann, M.E., Z. Zhang, M.K. Hughes, R.S. Bradley, S.K. Miller, S. Rutherford, and F. Ni. 2008. Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia. *Proceedings of the National Academy of Sciences* 105:13252–13257. Available online at http://www.ncdc.noaa.gov/paleo/pubs/mann2008/mann2008.html. Accessed July 14, 2010.

Marquis, R.J., and C.J. Whelan. 1994. Insectivorous birds increase growth of white oak through consumption of leaf-chewing insects. *Ecology* 75:2007–2014.

Marshall, D.A., and J. Lyons. 2008. Documenting and halting declines of nongame fishes in southern Wisconsin. Pages 171–181 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Martin, P.S., and C.R. Szuter. 2002. Game parks before and after Lewis and Clark: reply to Lyman and Wolverton. *Conservation Biology* 16:244–247.

McIntyre, J.W. 1988. *The Common Loon: spirit of northern lakes.* University of Minnesota Press, Minneapolis. 228 pp.

Messeling, E. 1953. Rattlesnakes in southwestern Wisconsin. *Wisconsin Conservation Bulletin* 18(10):21–23.

Mladenoff, D.J., M.K. Clayton, S.D. Pratt, T.A Sickley, and A.P. Wydeven. 2009. Changes in occupied wolf habitat in the Northern Great Lakes Region. Pages 119–138 *in* A. P. Wydeven, T. R. Van Deelen, and E. J. Heske, editors. *Recovery of gray wolves in the Great Lakes region of the United States: an endangered species success story*. Springer, New York. 350 pp.

Mladenoff, D.J., L.A. Schulte, and J. Bolliger. 2008. Broad-scale changes in the northern forests: from past to present. Pages 61–73 *in* D. M. Waller and T. P. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. 1995. A regional landscape analysis and prediction of favorable wolf habitat in the northern Great Lakes region. *Conservation Biology* 9:279–294.

National Research Council. 2006. *Surface temperature reconstructions for the last 2,000 years*. The National Academies Press, Washington D.C. 160 pp. Available online at http://www.nap.edu/catalog/11676.html. Accessed March 3, 2010.

Nichols, S. 2008. Shifting plants in Wisconsin lakes. Pages 211–227 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Nowacki, G., and M. Abrams. 2008. The demise of fire and the "mesophication" of forests in the eastern United States. *BioScience* 58(2):123–138.

Nuzzo, V., J. Maerz, and B. Blossey. 2009. Earthworm invasion as the driving force behind plant invasion and community change in northeastern North American forests. *Conservation Biology* 23(4):966–974.

Petersen, L.R. 1997. *Experimental management program for Bobwhite Quail.* Wisconsin Department of Natural Resources, Pittman-Robertson Final Report 112, Madison. 24 pp.

Petit, J.R., J. Jouzel, D. Raynaud, N.I. Barkov, J. M. Barnola, I. Basile, M. Bender, J. Chappellaz, M. Davis, G. Delaygue, M. Delmotte, V.M. Kotlyakov, M. Legrand, V.Y. Lipenkov, C. Lorius, L. Pepin, C. Ritz, E. Saltzman, and M.

Stievenard. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 399:429–436.

Poole, A.F., R.O. Bierregaard, and M.S. Martell. 2002. Osprey (Pandion haliaetus). *In* A. Poole and F. Gill, editors. *The Birds of North America, No. 683*. The Birds of North America, Inc., Philadelphia, Pennsylvania.

Quamen, F.R. 2004. *Distribution and productivity of Bald Eagles and Ospreys in Wisconsin (1974–1999).* M.S. Thesis. University of Wisconsin–Stevens Point, Stevens Point. 41 pp.

Radeloff, V.C., R.B. Hammer, and S.I. Stewart. 2005. Sprawl and forest fragmentation in the U.S. Midwest from 1940 to 2000. *Conservation Biology* 19:793–805.

Rogers, D., T. Rooney, D. Olson, and D. Waller. 2008. Shifts in southern Wisconsin forest canopy and understory richness, composition, and heterogeneity. *Ecology* 89(9):2482–2492.

Rolley, R.E., and M.L. Worland. 2009a. *Black bear population analysis 2009.* Wisconsin Department of Natural Resources, Madison. Available online at http://dnr.wi.gov/topic/wildlifehabitat/reports.html. Accessed April 2010.

Rolley, R.E., and M.L. Worland. 2009b. Otter population analysis. Wisconsin Department of Natural Resources, Madison. Available online at http://dnr.wi.gov/topic/wildlifehabitat/reports.html. Accessed April 2010.

Rooney, T., S. Wiegmann, D. Rogers, and D. Waller. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. *Conservation Biology* 18:787–798.

Sample, D.W., and M.J. Mossman. 1997. *Managing habitat for grassland birds: a guide for Wisconsin.* Wisconsin Department of Natural Resources, Bureau of Integrated Science Services, PUB-SS-925-97, Madison.

Sample, D.W., and M.J. Mossman. 2008. Two centuries of changes in grassland bird populations and their habitats in Wisconsin. Pages 301–329 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Sauer, J.R., J.E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr., and W.A. Link. 2011. The North American breeding bird survey, results and analysis 1966–2010. Version 12.07.2011, USGS Patuxent Wildlife Research Center, Laurel, Maryland.

Schoenebeck, A.J. 1902. *Birds of Oconto County*. Privately published, Kelly Brook, Wisconsin. Reprinted 1939 in *The Passenger Pigeon* 1(6):79–88 and 1(7):95–105. Available online at http://digital.library.wisc.edu/1711.dl/EcoNatRes.pp01n06 and http://digital.library.wisc.edu/1711.dl/EcoNatRes.pp01n07.

Schorger, A.W. 1937a. The great Wisconsin Passenger Pigeon nesting of 1871. *Proceedings of the Linnaean Society of New York* 48:1–26. Reprinted in K.M. Brockman and R.A. Dow Jr., editors. 1982. *Wildlife in early Wisconsin: a collection of works by A.W. Schorger*. Student Chapter of The Wildlife Society, Stevens Point, Wisconsin.

Schorger, A.W. 1937b. The range of the bison in Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 30:117–130. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1937.

Schorger, A.W. 1942a. Extinct and endangered mammals and birds of the upper Great Lakes region. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 34:23–44. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1942.

Schorger, A.W. 1942b. The Wild Turkey in early Wisconsin. *The Wilson Bulletin* 54(3):173–182. Available online at http://elibrary.unm.edu/sora/Wilson/v054n03/p0173-p0182.pdf.

Schorger, A.W. 1943. The Prairie Chicken and Sharp-tailed Grouse in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 35:1–59. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1943.

Schorger, A.W. 1944. The Quail in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 36:77–103. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1944.

Schorger, A.W. 1945. The Ruffed Grouse in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters* 37:35–90. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1945.

Schorger, A.W. 1946. The Passenger Pigeon in Wisconsin and the problems in its history. Delivered at annual meeting of Wisconsin Society for Ornithology, Appleton, April 6, 1946. Reprinted in K.M. Brockman and R.A. Dow Jr., editors. 1982. *Wildlife in early Wisconsin: a collection of works by A.W. Schorger*. Student Chapter of The Wildlife Society, Stevens Point, Wisconsin.

Schorger, A.W. 1947. The introduction of pheasants into Wisconsin. *The Passenger Pigeon* 9(3):101–102. Available online at http://digital.library.wisc.edu/1711.dl/EcoNatRes.pp09n03.

Schorger, A.W. 1949. The black bear in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 39:151–194. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1947.

Schorger, A.W. 1953. The white-tailed deer in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 42:197–247. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1953.

Schorger, A.W. 1954. The elk in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 43:5–23. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1954.

Schorger, A.W. 1956. The moose in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 45:1–10. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1956.

Schorger, A.W. 1964. The Trumpeter Swan as a breeding bird in Minnesota, Wisconsin, Illinois, and Indiana. *The Wilson Bulletin* 76(4):331–338. Available online at http://elibrary.unm.edu/sora/Wilson/v076n04/p0331-p0338.pdf.

Schorger, A.W. 1965. The beaver in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 54:147–179. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1965.

Schorger, A.W. 1967. Rattlesnakes in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 56:29–48. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1967.

Schorger, A.W. 1970. The otter in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 58:129–146. Available online at http://digital.library.wisc.edu/1711.dl/WI.WT1970.

Schulte, L.A., and D.J. Mladenoff. 2001. The original U.S. public land survey records: their use and limitations in reconstructing pre-European settlement vegetation. *Journal of Forestry* 99:5–10.

Seton, E.T. 1929. *The lives of game animals*. Doubleday, New York.

Shuman, B., A.K. Henderson, C. Plank, I. Stefanova, and S.S. Ziegler. 2009. Woodland-to-forest transition during prolonged drought in Minnesota after ca. AD 1300. *Ecology* 90:2792–2807.

Shuman, B.N., P.C. Newby, Y. Huang, and T. Webb III. 2004. Evidence for the close climatic control of New England vegetation history. *Ecology* 85:1297–1310.

Southeastern Wisconsin Regional Planning Commission (SEWRPC). 1997. *A regional Natural Areas and critical species habitat protection and management plan for southeastern Wisconsin.* Southeastern Wisconsin Regional Planning Commission, Planning Report No. 42, Waukesha, Wisconsin.

Swain, A.M. 1978. Environmental changes during the past 2000 years in north-central Wisconsin: analysis of pollen, charcoal, and seeds from varved lake sediments. *Quaternary Research* 10:55–68.

Temple, S.A., and J.R. Cary. 2008. Wisconsin's changing bird communities. Pages 331–337 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Thiel, R.P. 1985. The relationship between road densities and wolf habitat in Wisconsin. *American Midland Naturalist* 113:404–407.

Thiel, R.P. 1993. *The timber wolf in Wisconsin*. University of Wisconsin Press, Madison, Wisconsin. 253 pp.

Thiel, R.P., and R.J. Welch. 1981. Evidence of recent breeding activity in Wisconsin wolves. *American Midland Naturalist* 106:401–402.

Tweiten, M.A., S.C. Hotchkiss, R.K. Booth, R.R. Calcote and E.A. Lynch. 2009. The response of a jack pine forest to late-Holocene climate variability in northwestern Wisconsin. *The Holocene* 19:1049–1061.

Umbanhowar, C.E. 2004. Interaction of fire, climate and vegetation change at a large landscape scale in the Big Woods, Minnesota, USA. *The Holocene* 14:661–676.

University of Wisconsin Extension (UWEX) Center for Land Use Education. 2007. *Wisconsin land use megatrends: recreation.* University of Wisconsin Extension, Stevens Point. 8 pp.

University of Wisconsin Extension (UWEX) Center for Land Use Education. 2008. *Wisconsin land use megatrends: energy.* University of Wisconsin Extension, Stevens Point. 12 pp.

University of Wisconsin Extension (UWEX) Center for Land Use Education. 2009. *Wisconsin land use megatrends: housing.* University of Wisconsin Extension, Stevens Point. 8 pp.

U.S. Environmental Protection Agency (USEPA). 2010. Great Lakes monitoring: atmospheric deposition of toxic pollutants. Web page. Available online at http://www.epa.gov/greatlakes/glindicators/air/airb.html. Accessed October 25, 2010.

U.S. Geological Survey (USGS). 2008. Great Lakes Science Center, species restoration: lake trout. Web page. Available online at http://www.glsc.usgs.gov. Accessed March 18, 2010.

Waller, D., and T. Rooney, editors. 2008. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Webb, S.L. 1987. Beech range extension and vegetational history: pollen stratigraphy of two Wisconsin lakes. *Ecology* 68: 1993–2005.

Webb, T., III, K.H. Anderson, P.J. Bartlein, and R.S. Webb. 1998. Late Quaternary climate change in eastern North America: a comparison of pollen-derived estimates with climate model results. *Quaternary Science Reviews* 17:587–606.

Webb, T., III, P.J. Bartlein, S.P. Harrison, and K.H. Anderson. 1993. Vegetation, lake levels, and climate in eastern North America for the past 18,000 years. Pages 415–467 *in* H.E. Wright Jr., J.E. Kutzbach, T. Webb III, W.F. Ruddiman, F.A. Street-Perrot, and P.J. Bartlein, editors. *Global climates since the last Glacial Maximum*. University of Minnesota Press, Minneapolis.

Webb, T., III, E.J. Cushing, and H.E. Wright Jr. 1983. Holocene changes in the vegetation of the Midwest. Pages 142–165 *in* H.E. Wright Jr., editor. *Late-Quaternary environments of the United States*. Volume 2. The Holocene. University of Minnesota Press, Minneapolis.

Webster, K.E., J.M. Eilers, J.G. Wiener, G.E. Glass, P.J. Garrison, M.D. Johnson. 1993. *Chemical and biotic characteristics of two low-alkalinity lakes in northern Wisconsin: relation to atmospheric deposition.* Wisconsin Department of Natural Resources, Technical Bulletin 184, Madison.

Wetter, M., T. Cochrane, M. Black, H. Iltis, and P. Berry. 2001. Checklist of the vascular plants of Wisconsin. Wisconsin Department of Natural Resources, Technical Bulletin 192, Madison.

Wheeler, W.E., and J.M. Cole. 1990. The history and status of Wisconsin's resident Canada goose populations. Wisconsin Department of Natural Resources, Research Management Findings 26, Madison.

Whitman, C.O. 1919. *Orthogenetic evolution in pigeons*. Carnegie Institution of Washington, Washington, D.C.

Wiegmann, S., and D. Waller. 2006. Biotic homogenization in forest understories: identity and traits of historical "winners" and "losers." *Biological Conservation* 129:109–123.

Williams, B.W., J.H. Gilbert, and P.A. Zollner. 2007. *Historical perspective on the reintroduction of the fisher and American marten in Wisconsin and Michigan.* U.S. Forest Service, Northern Research Station, General Technical Report NRS-5, Newton Square, Pennsylvania. 29 pp.

Williams, J.W., B. Shuman, P.J. Bartlein, N.S. Diffenbaugh, and T. Webb III. 2010. Rapid, time-transgressive, and variable responses to early Holocene midcontinental drying in North America. *Geology* 38:135–138.

Winkler, M.G. 1988. Effect of climate on development of two Sphagnum bogs in south-central Wisconsin. *Ecology* 69:1032–1043.

Winkler, M.G., A.M. Swain, and J.E. Kutzbach. 1986. Middle Holocene dry period in the northern midwestern United States: lake levels and pollen stratigraphy. *Quaternary Research* 25:235–250.

Wisconsin Department of Natural Resources (WDNR). 1995. *Wisconsin's biodiversity as a management issue: a report to Department of Natural Resources managers.* Wisconsin Department of Natural Resources, Madison.

Wisconsin Department of Natural Resources (WDNR). 1997. *Trumpeter swan fact sheet.* Wisconsin Department of Natural Resources, Madison.

Wisconsin Department of Natural Resources (WDNR). 2000. *Wisconsin forests at the millennium: an assessment.* Wisconsin Department of Natural Resources, PUB-FR-161-2000, Madison.

Wisconsin Department of Natural Resources (WDNR). 2005. *Wisconsin's strategy for wildlife species of greatest conservation need.* Wisconsin Department of Natural Resources, Wisconsin Wildlife Action Plan, PUB-ER-641 2005, Madison. Available online at http://dnr.wi.gov/, keywords "wildlife action plan."

Wisconsin Department of Natural Resources (WDNR). 2008a. *Beaver damage control.* Wisconsin Department of Natural Resources, Bureau of Wildlife Management, PUBL WM-007-05 REV, Madison. Available online at http://dnr.wi.gov/topic/waterways/factsheets/beaverdamage.pdf. Accessed April 2008.

Wisconsin Department of Natural Resources (WDNR). 2008b. History of dams in Wisconsin. Web page. Updated February 11, 2003. Available online at http://dnr.wi.gov/topic/dams/history.html. Accessed July 2008.

Wisconsin Department of Natural Resources (WDNR). 2009a. *Wisconsin's forestland woody biomass harvesting guidelines.* Wisconsin Department of Natural Resources, PUB-FR-435-2009, Madison.

Wisconsin Department of Natural Resources (WDNR). 2009b. *Wisconsin Natural Heritage Working List.* April 2009. Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison. Current Working List available online at http://dnr.wi.gov/, keyword "NHI." Accessed March 11, 2010. *(Note: The Wisconsin Natural Heritage Working List is dynamic and updated periodically as new information is available. The April 2009 Working List was used for this book. Those with questions regarding species or natural communities on the Working List should contact Julie Bleser, Natural Heritage Inventory Data Manager, Bureau of Natural Heritage Conservation, Wisconsin DNR at (608) 266-7308 or julie.bleser@wisconsin.gov.)*

Wisconsin Department of Natural Resources (WDNR). 2010. 2010 Wisconsin Water Quality Report to Congress. Wisconsin Department of Natural Resources, PUB-WT-924-2010, Madison.

Wisconsin Department of Natural Resources (WDNR) 2012. *Management and conservation plan for American martens in Wisconsin.* Wisconsin Department of Natural Resources, Bureau of Endangered Resources, Madison. Available online at http://dnr.wi.gov/files/pdf/pubs/er/er0697.pdf.

Wisconsin Geological and Natural History Survey (WGNHS). 2010. Wisconsin's glacial landscapes. Web page. Available online at http://wgnhs.uwex.edu. Accessed January 28, 2010.

Worland, M., K. Martin, and L. Gregg. 2009. Spruce grouse distribution and habitat relationships in Wisconsin. *The Passenger Pigeon* 71(1):5–18.

Wydeven, A.P., and C.M. Pils. 2008. Changes in mammalian carnivore populations. Pages 257–272 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Wydeven, A.P., J.E. Wiedenhoeft, R.N. Schultz, R.P. Thiel, R.L. Jurewicz, B.E. Kohn, and T.R. Van Deelen. 2009. History, population growth, and management of wolves in Wisconsin. Pages 87–106 *in* A.P. Wydeven, T.R. Van Deelen, and E.J. Heske, editors. *Recovery of gray wolves in the Great Lakes region of the United States: an endangered species success story*. Springer Science, New York. 350 pp.

Zedler, J.B., and K. Potter. 2008. Southern Wisconsin's herbaceous wetlands: their recent history and precarious future. Pages 193–210 *in* D. Waller and T. Rooney, editors. *The vanishing present: Wisconsin's changing lands, waters, and wildlife*. University of Chicago Press, Chicago, Illinois. 416 pp.

Zhang, J., W. Wang, and L.R. Leung. 2008. Contribution of land-atmosphere coupling to summer climate variability over the contiguous United States. *Journal of Geophysical Research* 113:D22109, doi:10.1029/2008JD010136.

Zimmer, G.E. 1979. *The status and distribution of the common loon in Wisconsin.* M.S. Thesis. University of Wisconsin-Stevens Point, Stevens Point. 63 pp.

Additional References

Bogan, A.E. 2006. Conservation and extinction of the freshwater molluscan fauna of North America. Pages 373–383 in C.F. Sturm, TA. Pearce, and A. Valdés, editors. *The mollusks: a guide to their study, collection, and preservation.* American Malacological Society/Universal Publishers, Inc., Boca Raton, Florida.

Camill, P., C.E. Umbanhowar Jr., R. Teed, C.E. Geiss, J. Aldinger, L. Dvorak, J. Kenning, J. Limmer, and K. Walkup. 2003. Late-glacial and Holocene climatic effects on fire and vegetation dynamics at the prairie-forest ecotone in south-central Minnesota. *Journal of Ecology* 91:822–836.

Dey, D. 2002. Fire history and postsettlement disturbance. Pages 46–59 in W. McShea and M. Healy, editors. *Oak forest ecosystems: ecology and management for wildlife.* Johns Hopkins University Press, Baltimore, Maryland.

Fields, D. 2003. The vascular plants of Taylor County, Wisconsin. *The Michigan Botanist* 42(4):171–282.

Hansen, A., T. Spies, F. Swanson, and J. Ohmann. 1991. Conserving biodiversity in managed forests: lessons from natural forests. *BioScience* 41(6):382–391.

Hartley, T. 1960. The flora of the Driftless Area. *University of Iowa Studies in Natural History* 21:1–174.

Hastie, L.C., P.J. Cosgrove, N. Ellis, and M.J. Gaywood. 2003. The threat of climate change to freshwater pearl mussel populations. *Ambio* 32(1):40–46.

Havlik, M.E., and L.L. Marking. 1987. *Effects of contaminants on naiad mollusks (Unionidae): a review.* U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 164, Washington, D.C.

Hirai, K. 2010. Flowering plants are Michigan's fairest and rarest. Great Lakes Echo website. Knight Center for Environmental Journalism, Michigan State University, East Lansing. Available online at http://greatlakesecho.org/2010/05/18/flowering-plants-are-michigans-fairest-and-rarest/.

Judziewicz, E. 2003. Flora and vegetation of the Grand Traverse Islands (Lake Michigan), Wisconsin and Michigan. *The Michigan Botanist* 40(4):81–208.

Judziewicz, E., and R. Koch. 1993. Flora of the Apostle Islands. *The Michigan Botanist* 32(2):1–189.

Leach, M., and T. Givnish. 1996. Ecological determinants of species loss in remnant prairies. *Science* 273:1555–1558.

Lindborg, R., and O. Erickson. 2004. Historical landscape connectivity affects present plant species diversity. *Ecology* 85:1840–1845.

McIntyre, J.W., and J.F. Barr. 1997. Common Loon (*Gavia immer*) No. 313. In A. Poole and F. Gill, editors. *The birds of North America.* Academy of Natural Sciences, Philadelphia, Pennsylvania, and American Ornithologists Union, Washington, D.C.

McKinney, M., and J. Lockwood. 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Tree* 14(11):450–453.

Mudrak, E., S. Johnson, and D. Waller. 2009. Forty-seven year changes in the vegetation at the Apostle Islands: effects of deer on forest understories. *Natural Areas Journal* 29:167–175.

National Native Mussel Conservation Committee. 1998. National strategy for the conservation of native freshwater mussels. *Journal of Shellfish Research* 17(5):1419–1428.

Noss, R., E. LaRoe III, and J. Scott. 1995. *Endangered ecosystems of the United States: a preliminary assessment of loss and degradation.* U.S. Department of the Interior, National Biological Service, Biological Report No. 28, Washington, D.C.

Olden, J., and T. Rooney. 2006. On defining and quantifying biotic homogenization. *Global Ecology and Biogeography* 15:113–120.

Parmalee, P.W., and W.E. Klippel. 1974. Freshwater mussels as a prehistoric food resource. *American Antiquity* 39(3):421–434.

Peacock, E., W.R. Haag, and M.L. Warren Jr. 2005. Prehistoric decline in freshwater mussels coincident with the advent of maize agriculture. *Conservation Biology* 19(2):547–551.

Petersen, L.R., M.A. Martin, and C.M. Pils. 1977. *Status of fishers in Wisconsin.* Wisconsin Department of Natural Resources, Research Report 92, Madison.

Plant Ecology Laboratory of the University of Wisconsin–Madison. No date. Unpublished files of the Research Program, Plant Ecology Laboratory of the University of Wisconsin–Madison. University of Wisconsin–Madison, Botany Department, Madison.

Poole, K.E., and J.A. Downing. 2004. Relationship of declining mussel biodiversity to stream-reach and watershed characteristics in an agricultural landscape. *Journal of the North American Benthological Society* 23:114–125.

Robbins, S.D., D.W. Sample, P.W. Rasmussen, and M.J. Mossman. 1996. The breeding bird survey in Wisconsin: 1966–1991. *The Passenger Pigeon* 58:81–179.

Sample, D.W., and M.J. Mossman. 1997. *Managing habitat for grassland birds: a guide for Wisconsin.* Wisconsin Department of Natural Resources, Bureau of Integrated Science Services, PUB-SS-925-97, Madison.

Schneider, A.F., S.W. Leavitt, and T. Lange. 2009. Stratigraphy, age, and flora of the Southport forest bed, southeastern Wisconsin. J*ournal of Great Lakes Research* 35:538–547.

Strayer, D.L. 1999. Effects of alien species on freshwater mollusks in North America. *Journal of the North American Benthological Society* 18(1):74–98.

Temple, S.A., and J.R. Cary. 1988. Modeling dynamics of habitat-interior birds in fragmented landscapes. *Conservation Biology* 2(4):340–347.

Waller, D. 1988. Sharing responsibilities for conserving diversity: the complementary roles of conservation biologists and public land agencies. *Conservation Biology* 2(4):398–401.

Waller, D., S. Johnson, R. Collins, and E. Williams. 2009. *Threats posed by ungulate herbivory to forest structure and plant diversity in the upper Great Lakes region with a review of methods used to assess those threats.* National Park Service, National Resource Report NPS/GLKN/NRR-2009/102, Fort Collins, Colorado.

Webb, S.L. 1987. Beech range extension and vegetational history: pollen stratigraphy of two Wisconsin lakes. *Ecology* 68:1993–2005.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18(9):6–22.

Acknowledgments

John Lyons provided much needed expertise and advice on fish and aquatic ecology and provided technical review of the aquatic sections.

Julie Bleser interpreted Natural Heritage Inventory data, provided tables of endangered, threatened, and special concern species, and made distribution maps of rare species and natural community occurrences.

Mitch Moline, Kate Barrett, Bill Shockley, Nina Janicki, Sally Dahir, Kathy Hanson, Elizabeth Spencer, and Jennifer Skoloda performed GIS analyses, prepared maps, and provided other background materials.

Sarah Herrick and Jescie Kitchell provided editorial assistance and compiled data and other needed materials for this document.

Technical review of this chapter was provided by the following:

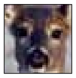
Changes during the Holocene: Jack Williams (UW-Madison)

Changes to Flora: Craig Anderson (Wisconsin DNR-Natural Heritage Conservation)

Changes to Fauna: Scott Craven (UW-Madison); Terrell Hyde (Wisconsin DNR-Natural Heritage Conservation); Lisie Kitchel (Wisconsin DNR-Natural Heritage Conservation); Keith McCaffery (Wisconsin DNR-Science Services); Rich Staffen (Wisconsin DNR-Natural Heritage Conservation); and Adrian Wydeven (Wisconsin DNR-Natural Heritage Conservation)

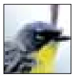
Detailed discussions on various topics for the book, including some that were pertinent to this chapter, were conducted with Andy Paulios, Mike Mossman, Bill (William A.) Smith, Sumner Matteson, Tom Bernthal, Pat Trochlell, Matt Dallman, Mike Grimm, Pat Robinson, and Randy Hoffman.

Sarah Shapiro Hurley, Signe Holtz, Darrell Zastrow, Paul DeLong, Laurie Osterndorf, Mark Aquino, Jack Sullivan, Karl Martin, and Steve Miller provided important administrative support for the project.



Funding

Funding for this project and publication of this report was provided by the Wisconsin Department of Natural Resources Divisions of Forestry, Lands, and Enforcement and Science; by grants from the Wisconsin Wildlife Action Plan Fund; and in part by funds from the Federal Aid to Wildlife Restoration Act under Pittman-Robertson Project W-160-P.



Authors

This chapter was authored by the Wisconsin Department of Natural Resources Ecosystem Management Planning Team members Jerry Bartelt, Owen Boyle, Eric Epstein, Vern Everson, Drew Feldkirchner, Eunice Padley, Jeff Schimpff, and Andy Stoltman. See "About the Authors" in Part 3, "Supporting Materials," for a description of team member expertise and experience.

Contributors

Important technical reviews, data interpretation, and editing were done by Wisconsin Department of Natural Resources Ecosystem Management Planning Team members Cathy Bleser and Lisa Helmuth on various topics covered by this book.

Credits

Publication assistance was provided by Dreux Watermolen. Patricia Duyfhuizen provided the edit, organizational advice, graphic design, and technical layout as well as many other helpful editing suggestions. Michelle Voss prepared graphs and provided assistance with other figures. Andy Stoltman, Wisconsin DNR-Forestry, produced the maps and prepared other cartographic presentations found in this publication.

Sources of photographs include the following: Nicholas Anich, Wisconsin DNR; Erwin and Peggy Bauer, U.S. Fish and Wildlife Service; Robert Burton, U.S. Fish and Wildlife Service; Brian Collins; Ryan O'Connor, Wisconsin DNR; Dean DiTomasso; Steve Emmons, U.S. Fish and Wildlife Service; Drew Feldkirchner, Wisconsin DNR; Ryan Hagerty, U.S. Fish and Wildlife Service; Kitty Kohout; Janeen Laatsch, Wisconsin DNR; Herbert Lange; Karl Martin, Wisconsin DNR; Thomas Meyer, Wisconsin DNR; Musser Public Library, Muscatine, Iowa; Robert Queen, Wisconsin DNR; Mike Reese; Vicki Sokolowski; Wisconsin Department of Natural Resources staff.

Sources of figures include the following: Elsevier; Linnaean Society of New York; Louis J. Maher, Department of Geoscience, University of Wisconsin-Madison; National Academy of Sciences; *Nature*; Wilson Ornithological Society; Wisconsin Academy of Sciences, Arts and Letters; Wisconsin Department of Natural Resources; Wisconsin Society for Ornithology.

WISCONSIN
DEPT. OF NATURAL RESOURCES

Printed on recycled paper

Wisconsin Department of Natural Resources
P.O. Box 7921, Madison, WI 53707

PUB-SS-1131E 2015